CERES Instrument Status Flight Models 1-6 (FM1-FM6)

Mohan Shankar

CERES Instrument Working Group

CERES Fall Science Team Meeting
October 12, 2021

CERES Instrument Working Group

CERES Instrument Working Group

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Cian Branco	Dianne Snyder	Nitchie Smith
Adam Horn		Z. Peter Szewczyk
Carol Kelly		Robert Wilson
William Edmonds		
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CERES Instrument Operations

- **Operation modes**
  - **Flight Models 1-3, FM6 are operating in Crosstrack mode.**
  - **FM4 is operating in biaxial mode since July 14, 2021.**
  - **FM5 is operating in Full biaxial mode since Mar 23, 2020.**

- **Successfully conducted a reset of the Solid State Recorder Data Memory Unit for Terra on September 22, 2021 to fix an anomaly.**
  - FM1 and FM2 were commanded to SAFE mode during the event.

- **First ever pitch-over maneuver for Deep Space Cal for Aqua successfully completed on September 23, 2021.**
  - CERES instruments on Aqua collected data to quantify the scan dependent offsets during the event.

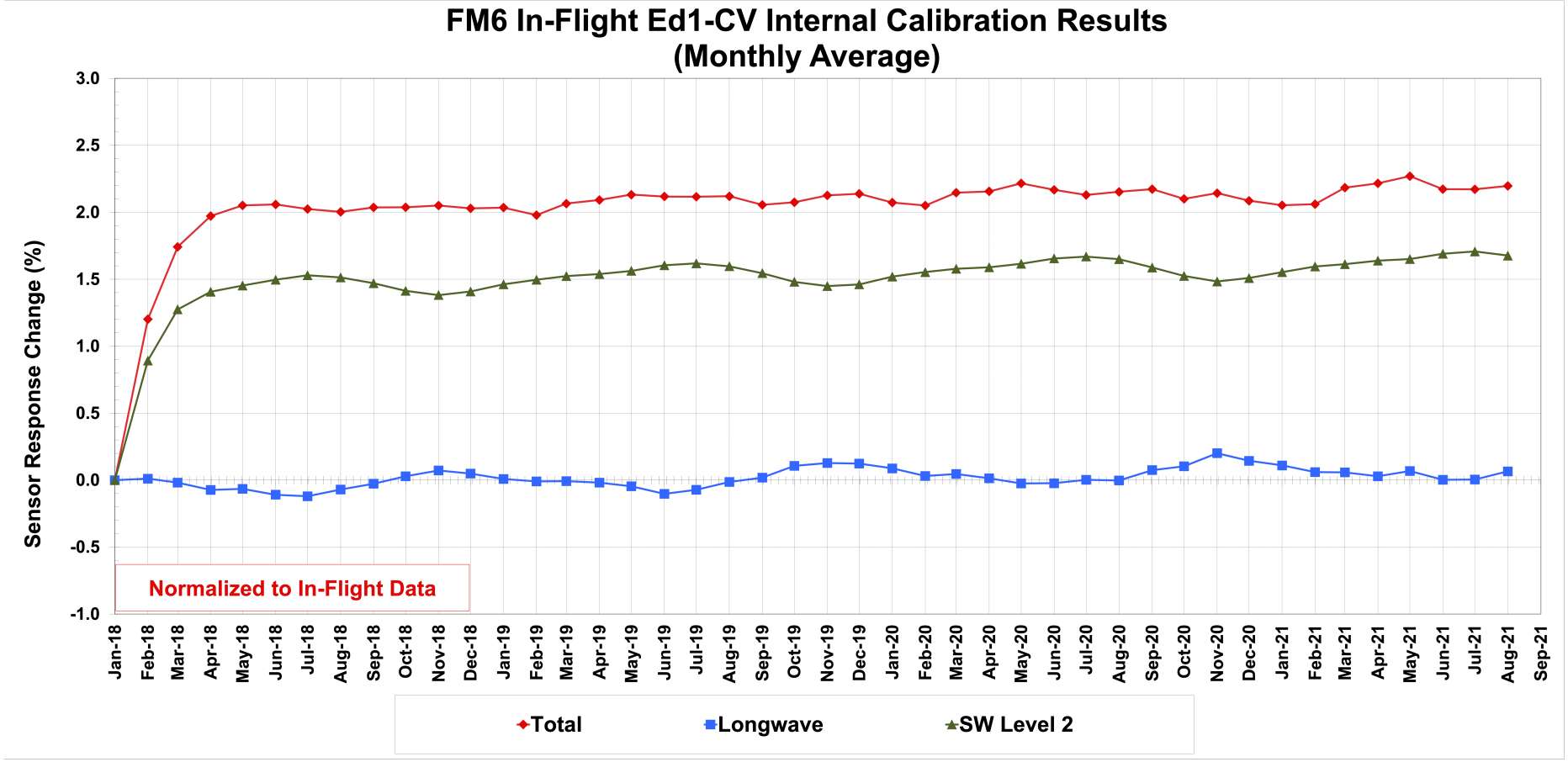
- **Inter-comparison operations completed in summer 2021:**
  - Terra/FM1 – S-NPP/FM5: May 1 – Jul 31, 2021
  - Terra/FM1 – NOAA-20/FM6: May 1 – Jul 31, 2021
  - Terra/FM1 – Aqua/FM3: Jun 1 – 30, 2021
  - Terra/FM2 – GERB: Jun 1 – 30, 2021

Overpass region around 70^0 N

NOAA-20/FM6 Instrument Status

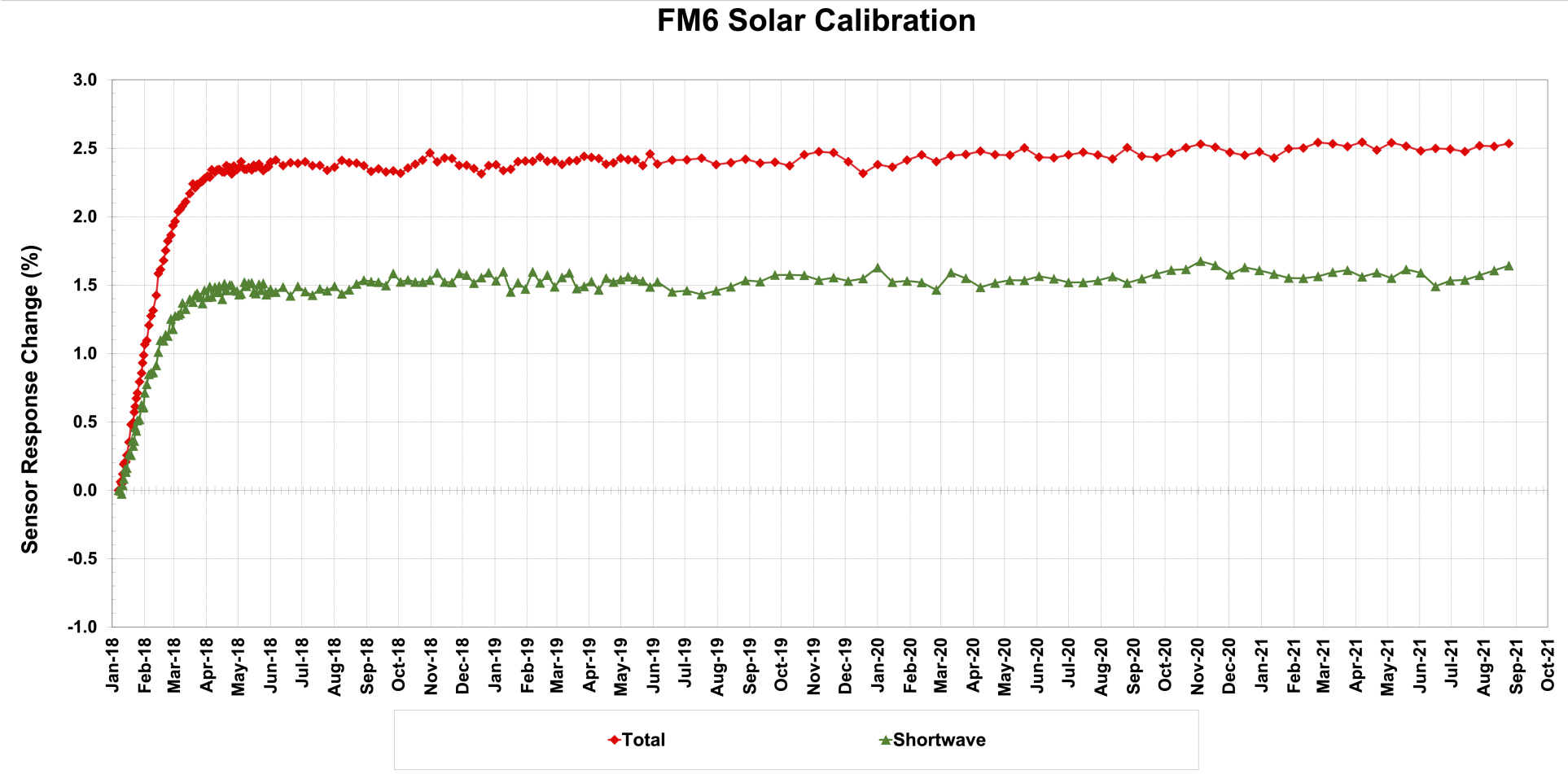
FM6 Internal Calibration

- For SW and TOT channels, the responses to the on-board sources (SWICS lamp and Blackbodies) continue to be stable after the initial rise of ~1.5% (SW) and ~2.2% (TOT) since start of mission.
- LW Channel (calibrated using blackbody) continues to show very little change.



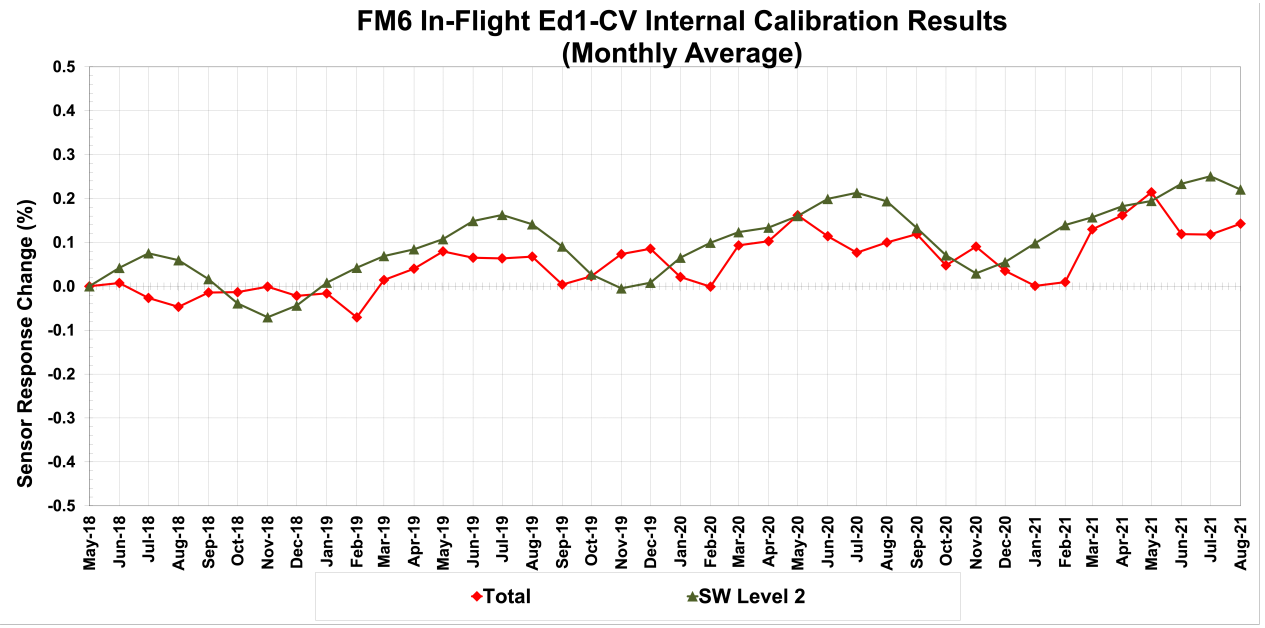
FM6 Solar Calibration

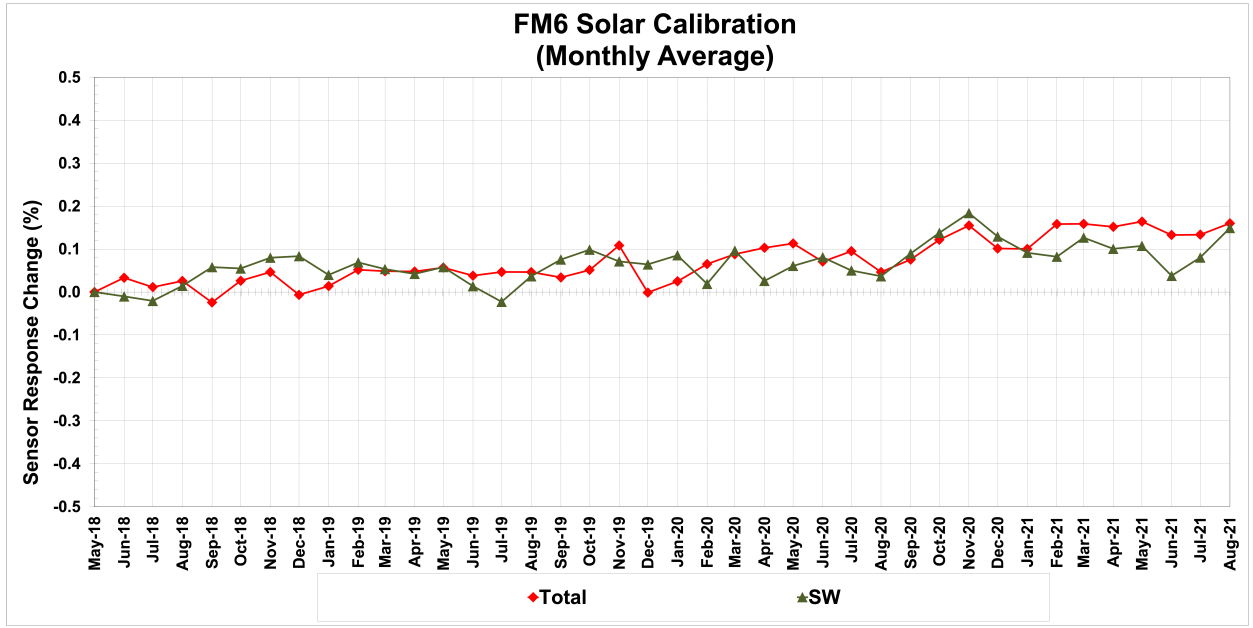
- **Response of the SW and TOT channels while viewing the MAM that is illuminated by the sun.**
- **After the initial rise of ~1.5% for SW, and ~2.3% for TOT, the response is stable.**



FM6 Calibration- Internal and Solar Cal Since May 2018

FM6 Internal and solar calibration results show consistently little change in sensor response (~0.2%) since May 2018.





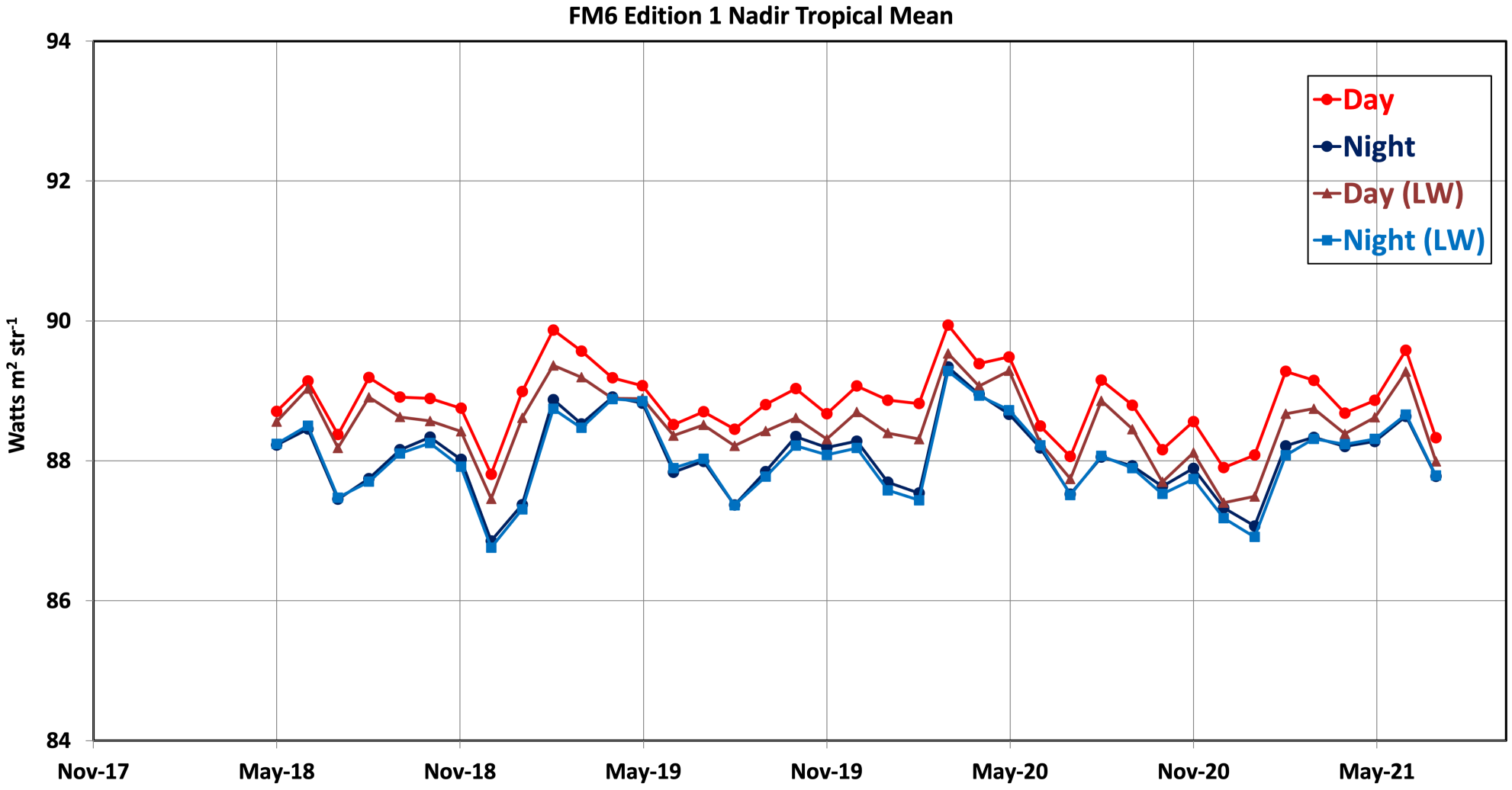
Validation – Tropical Mean

- Average of the ES-8 Nadir radiances over Tropical ocean (20^0N-20^0S) scenes under All-sky conditions.
- Two sets of TM Day-Night Differences (DN) are calculated:
  - TOT and SW sensors

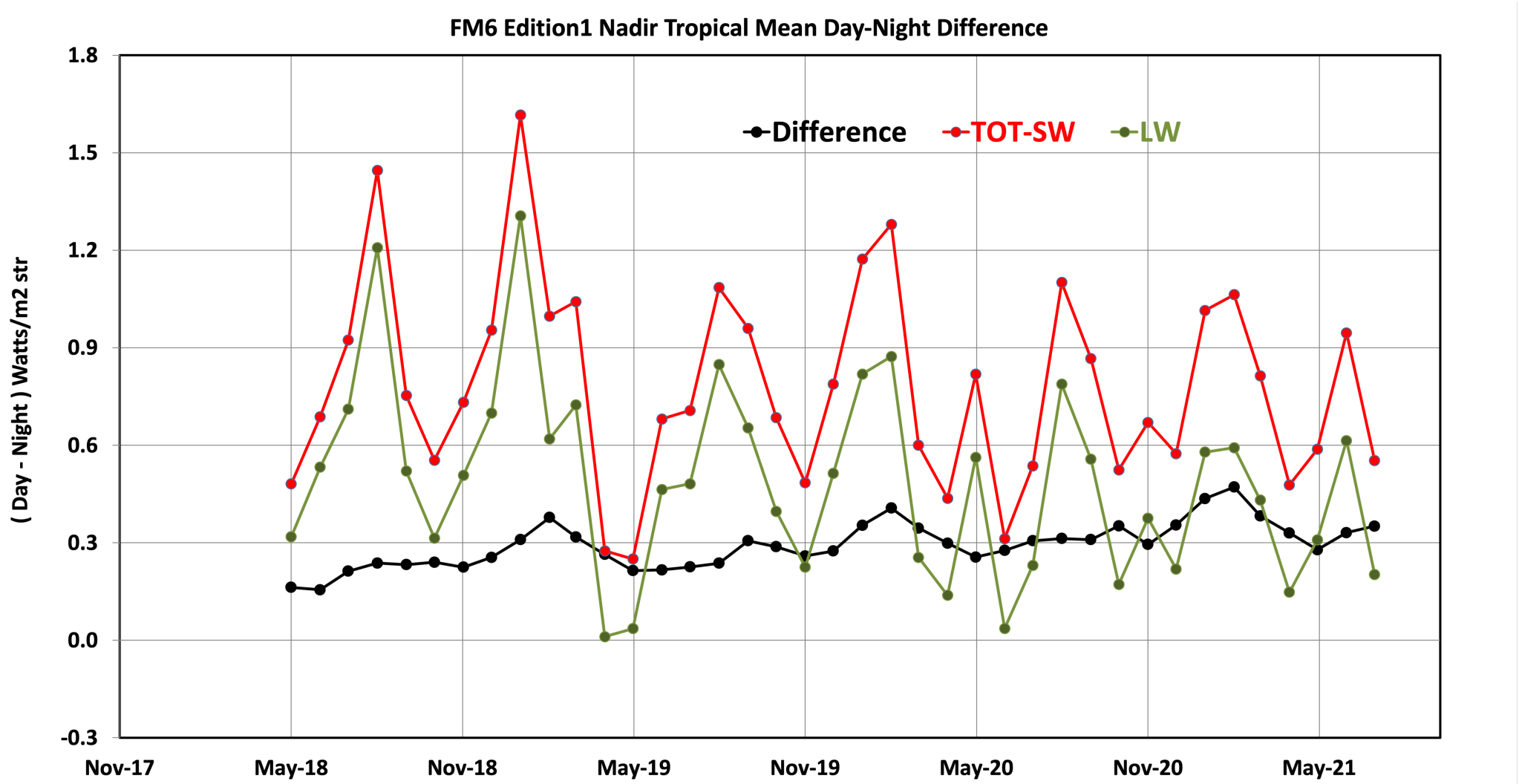
    $DN = TM_D(TOT\text{-}SW) - TM_N(TOT)$
  - LW sensor

    $DN = TM_D(LW) - TM_N(LW)$
- Difference in the two DN values highlight any inconsistencies in the shortwave regions of the sensors.

Validation- FM6 Tropical mean



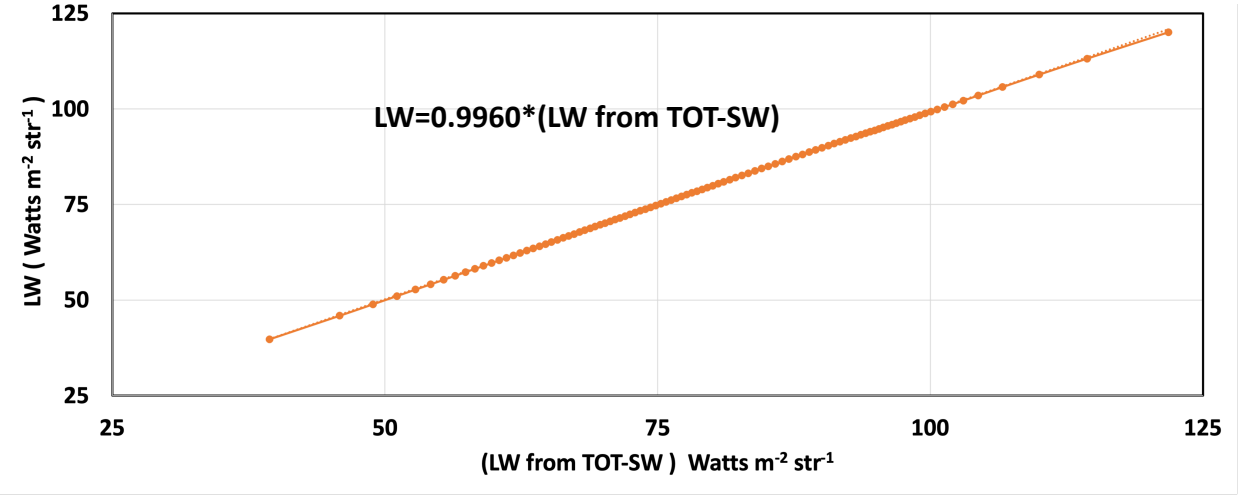
Validation- FM6 Tropical mean Day-Night



FM6 3-channel Consistency check- Global LW Day and Night

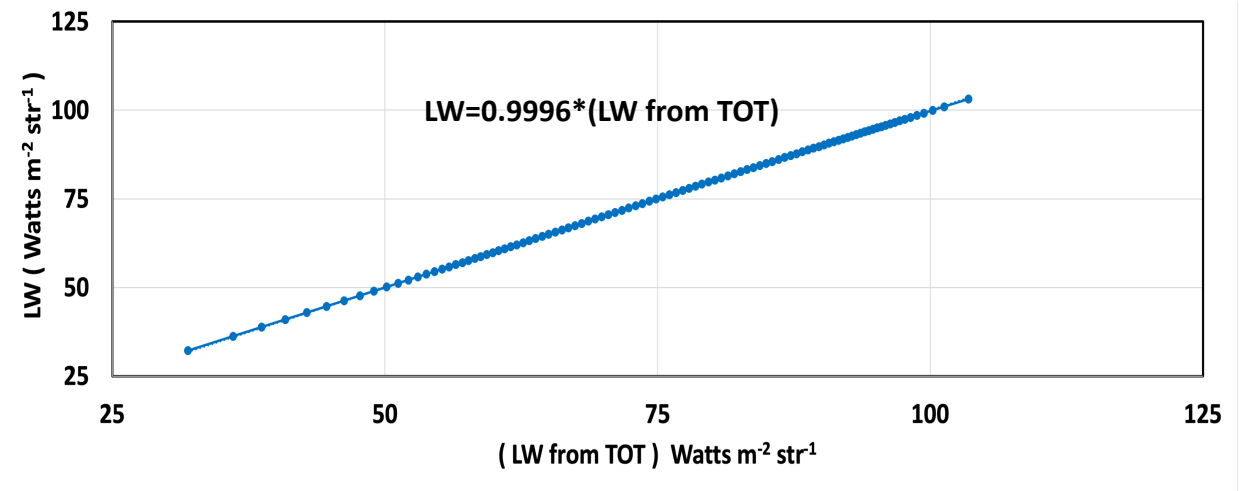
May 2018 - Jul 2021

Daytime Global Edition 1 ES-8 Nadir
LW from TOT- SW vs. LW sensor



Daytime
LW_{TOT-SW} - LW_{LWc}= 0.4%

Nighttime Global Edition 1 ES-8 Nadir
LW from TOT vs. LW sensor



Nighttime
LW_{TOT} - LW_{LWc}= 0.04%

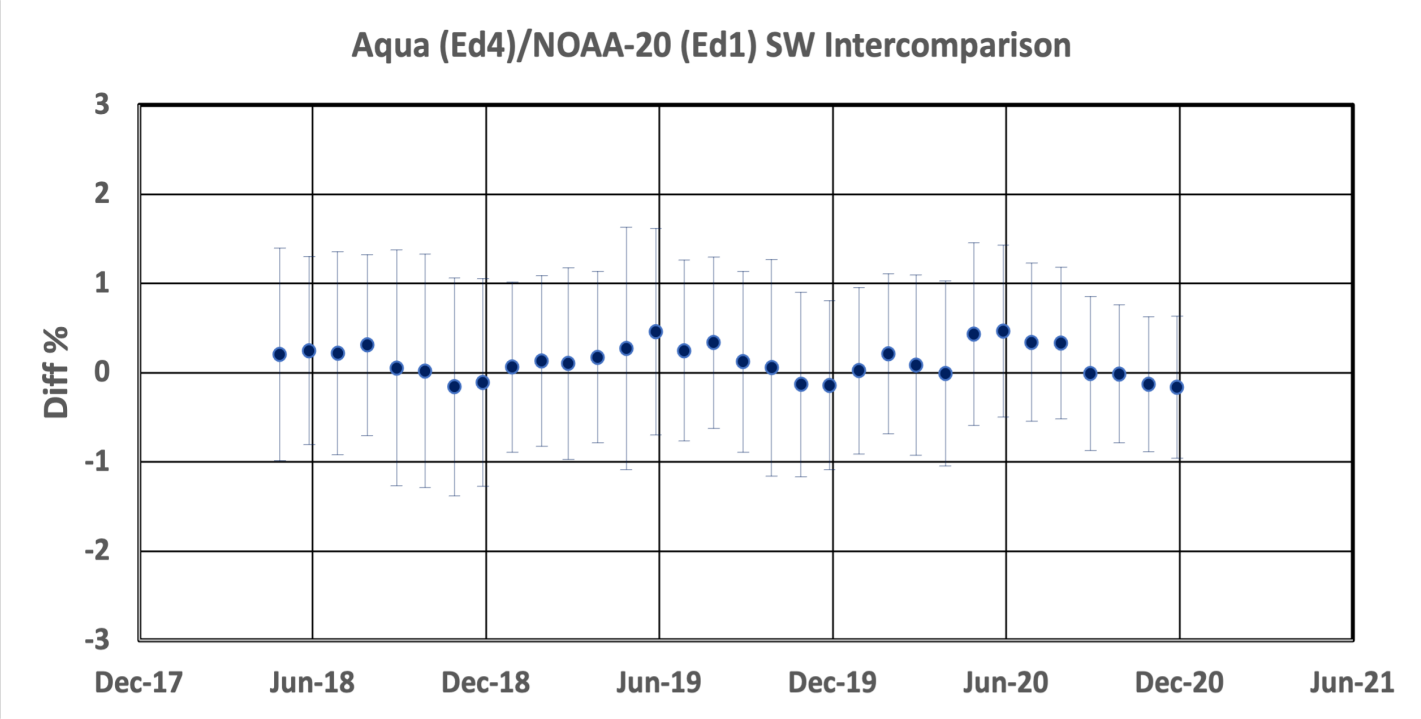
Aqua/NOAA-20 Intercomparisons

- The orbital geometries for Aqua and NOAA-20 are such that orbital overlaps occur every ~64 hours.
- Obtain spatially and temporally matched observations during every crossover.
- Use matching criteria to subset the data:
  - Lat. and Long. difference <= **0.05^0**
  - SZA, VZA difference < **2.0^0**
  - RAZ difference < **5^0**
- Obtain monthly all-sky SW reflectance, daytime and nighttime LW radiance differences using the matched footprints.

FM3/FM6 SW All-sky Inter-comparisons: May 2018- Dec 2020

Difference of Reflectance:
FM3-FM6 %, 95% CI

$$Reflectance = \frac{SW_{rad} * \pi}{F * \cos(SZA)}$$ F=1361 W/m^2



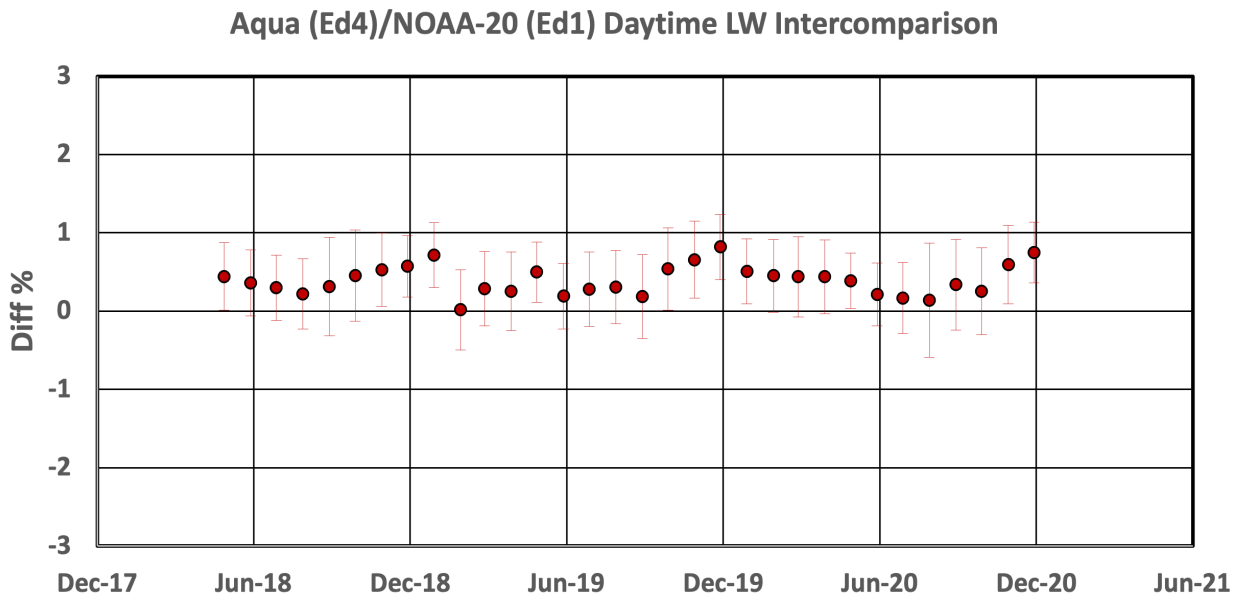
Radiometric scaling of FM6 to FM3 done in May 2018.

Data:
CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM6-VIIRS_Edition1A (not public)

FM3/FM6 LW All-sky Inter-comparisons: May 2018-Dec 2020

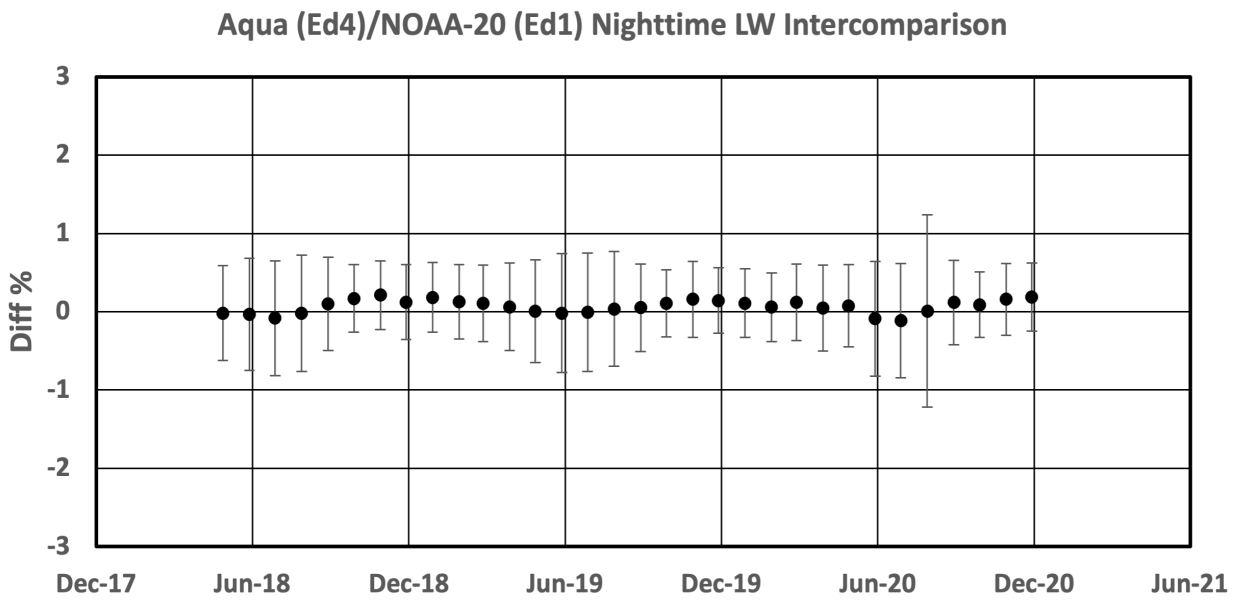
Difference of Daytime Radiance: FM3-FM6 %, 95% CI

Daytime LW for FM6 obtained from TOT -SW



Difference of Nighttime Radiance: FM3-FM6 %, 95% CI

Nighttime LW for FM6 obtained from TOT



Radiometric scaling of FM6 to FM3 done in May 2018.

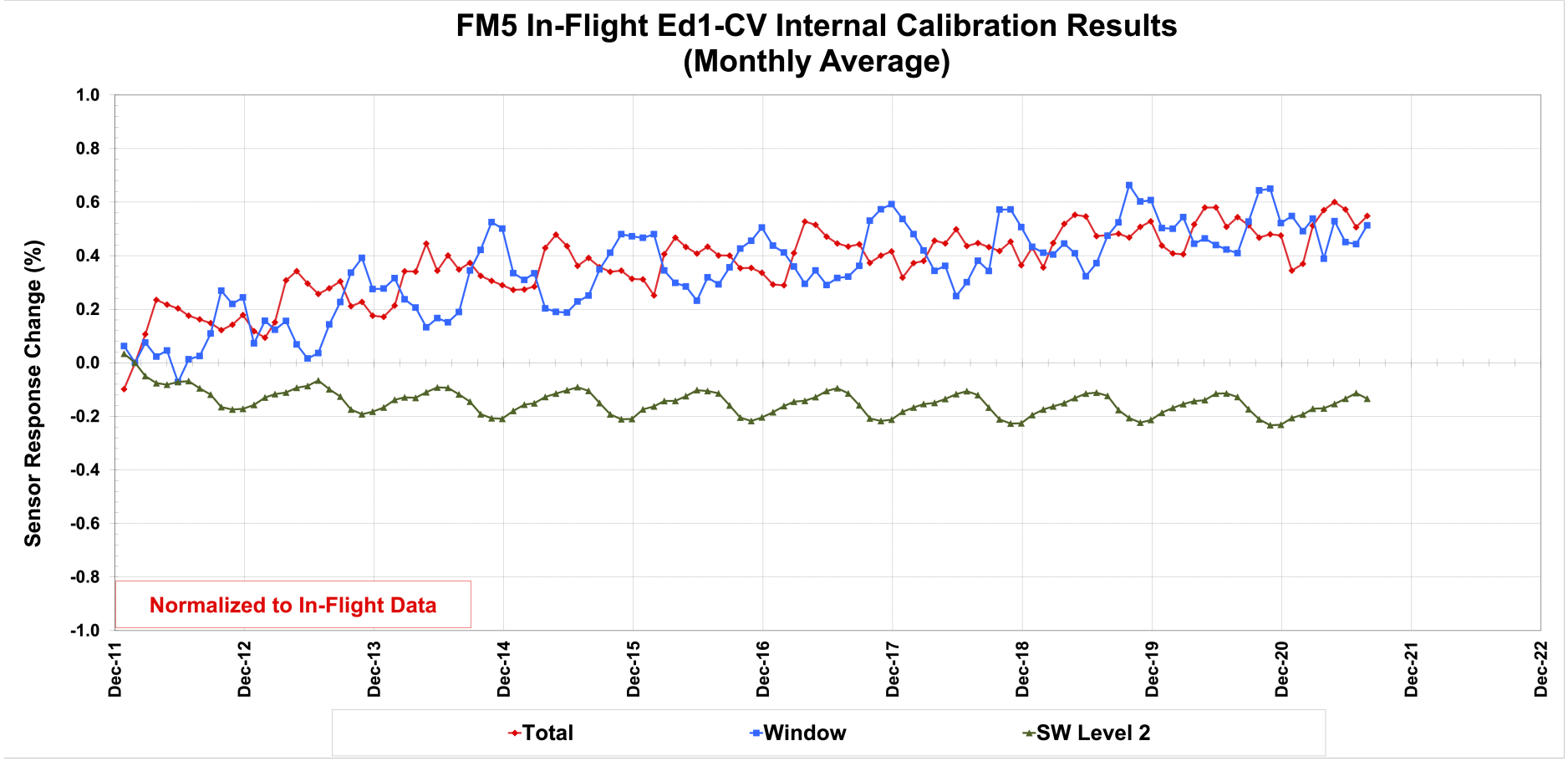
Data:
CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM6-VIIRS_Edition1A (not public)

S-NPP/FM5 Instrument Status

FM5 Internal Calibration

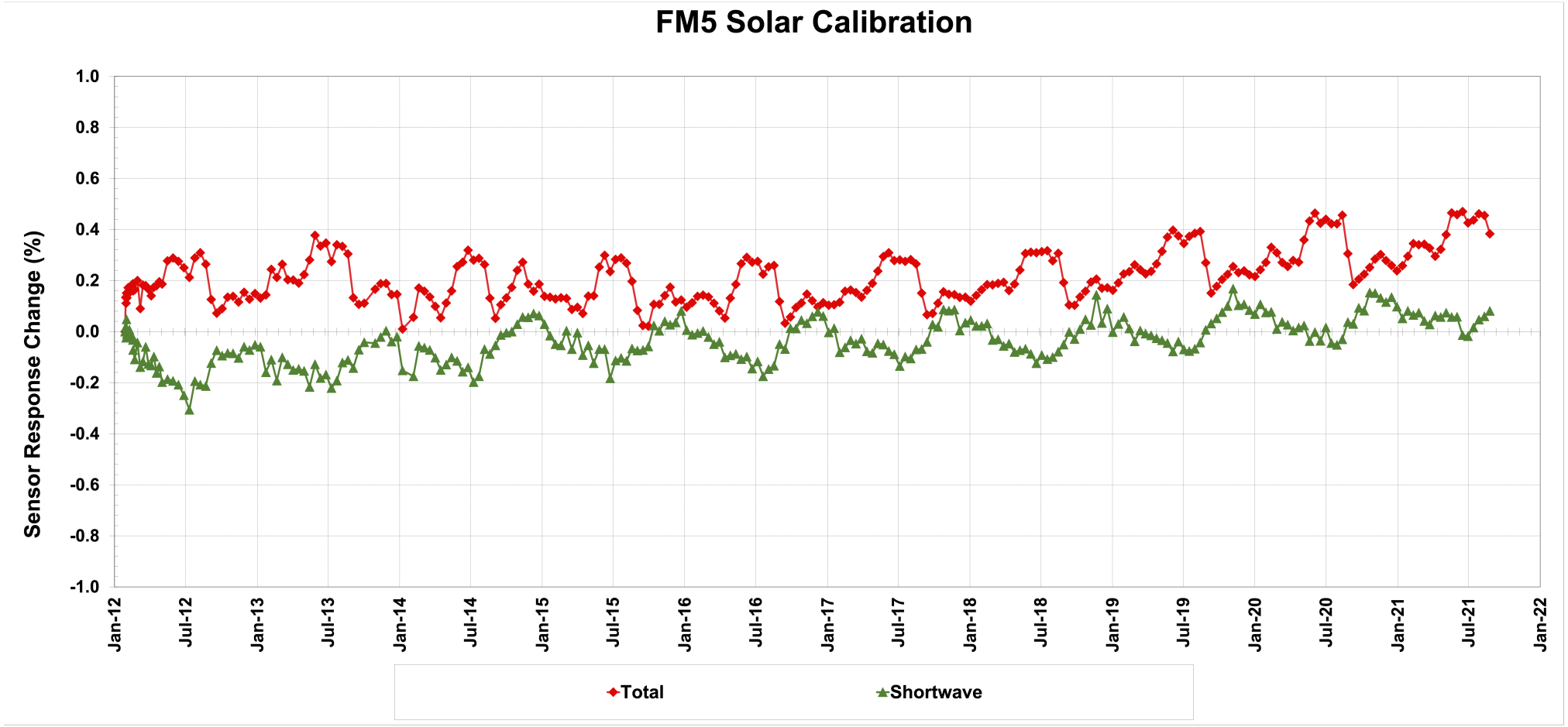
In response to the blackbodies, the FM5 TOT and WN sensors show a ~0.5% rise since start of mission.

SW channel's response to the SWICS has settled at ~-0.2% since start of mission.

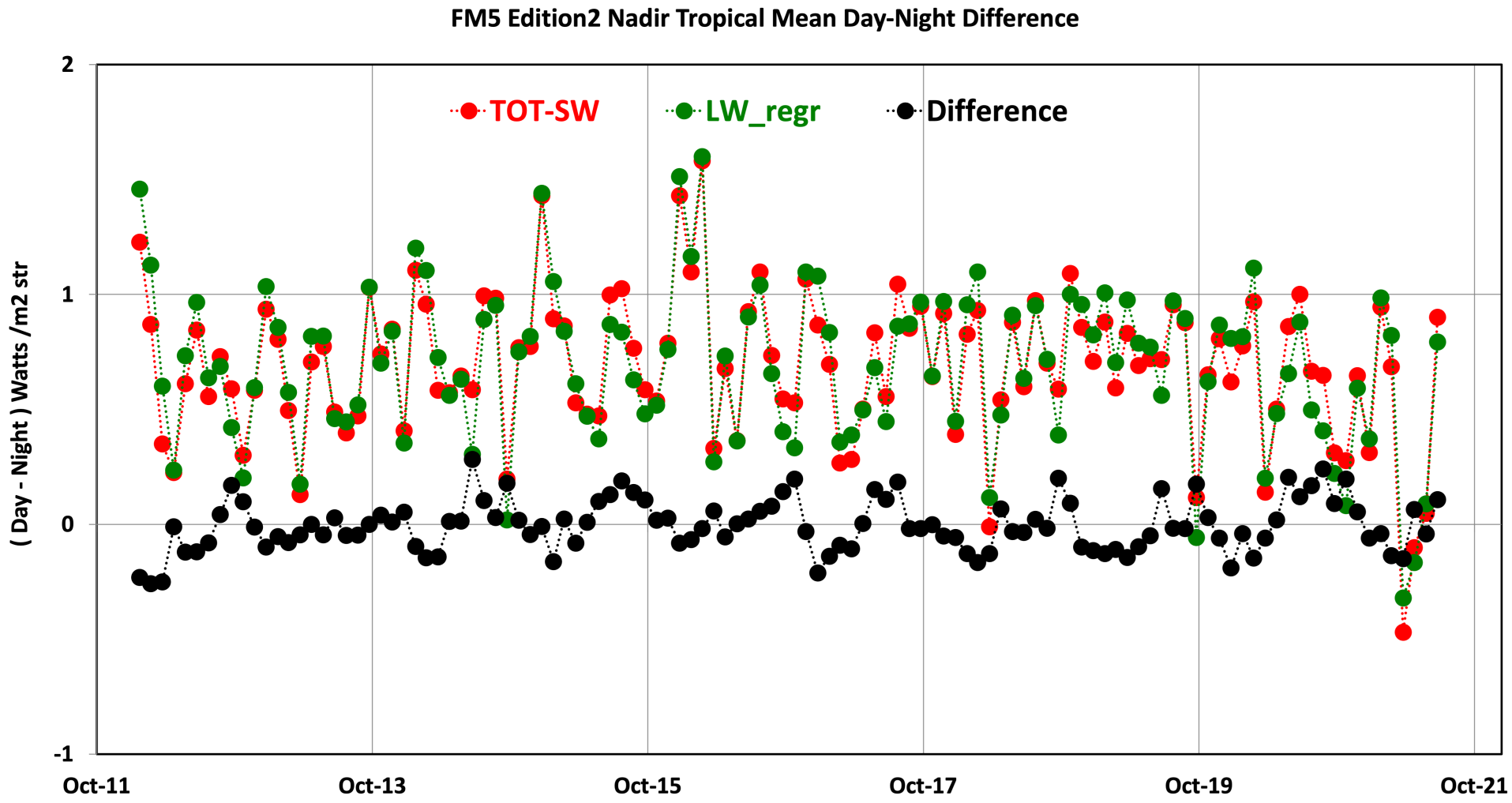


FM5 Solar Calibration

- **FM5 Solar calibration results show the MAMs are very stable.**
- **TOT and SW responses show a slight upward trend in latter part of mission.**



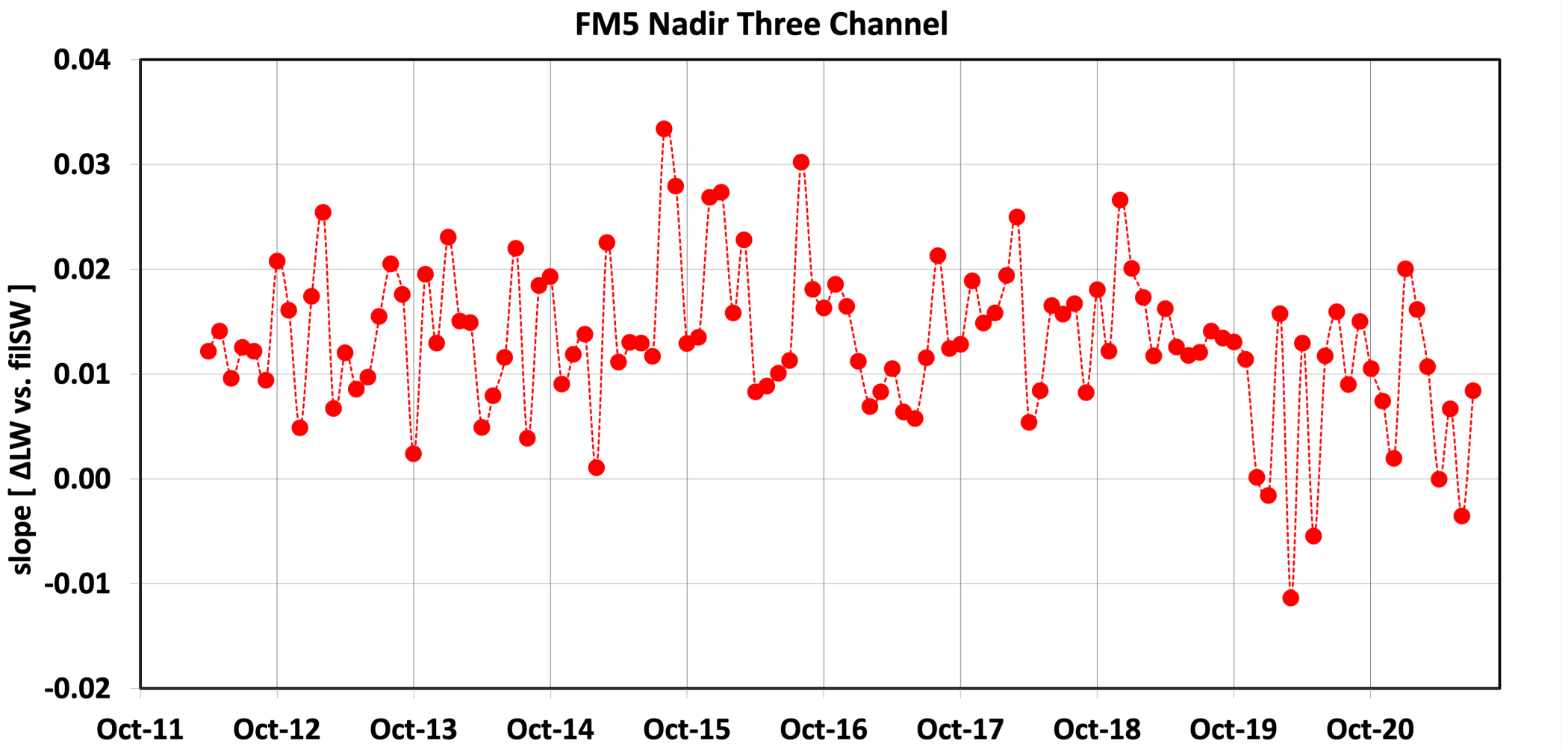
Validation- FM5 Tropical Mean



Validation: DCC 3-Channel Inter-comparison

- Compare the ES-8 nadir radiances from the three sensors of the instrument when viewing Deep Convective Clouds (DCC).
- Two sets of longwave (LW) radiances obtained:
  - TOT and SW sensors
  - Trained WN sensor
- Monitor the trend between the difference of the two LW radiances in relation to the SW radiance.
- Highlights any inconsistencies in the SW sensor or the shortwave part of the TOT sensor.

DCC 3-Channel Intercomparison



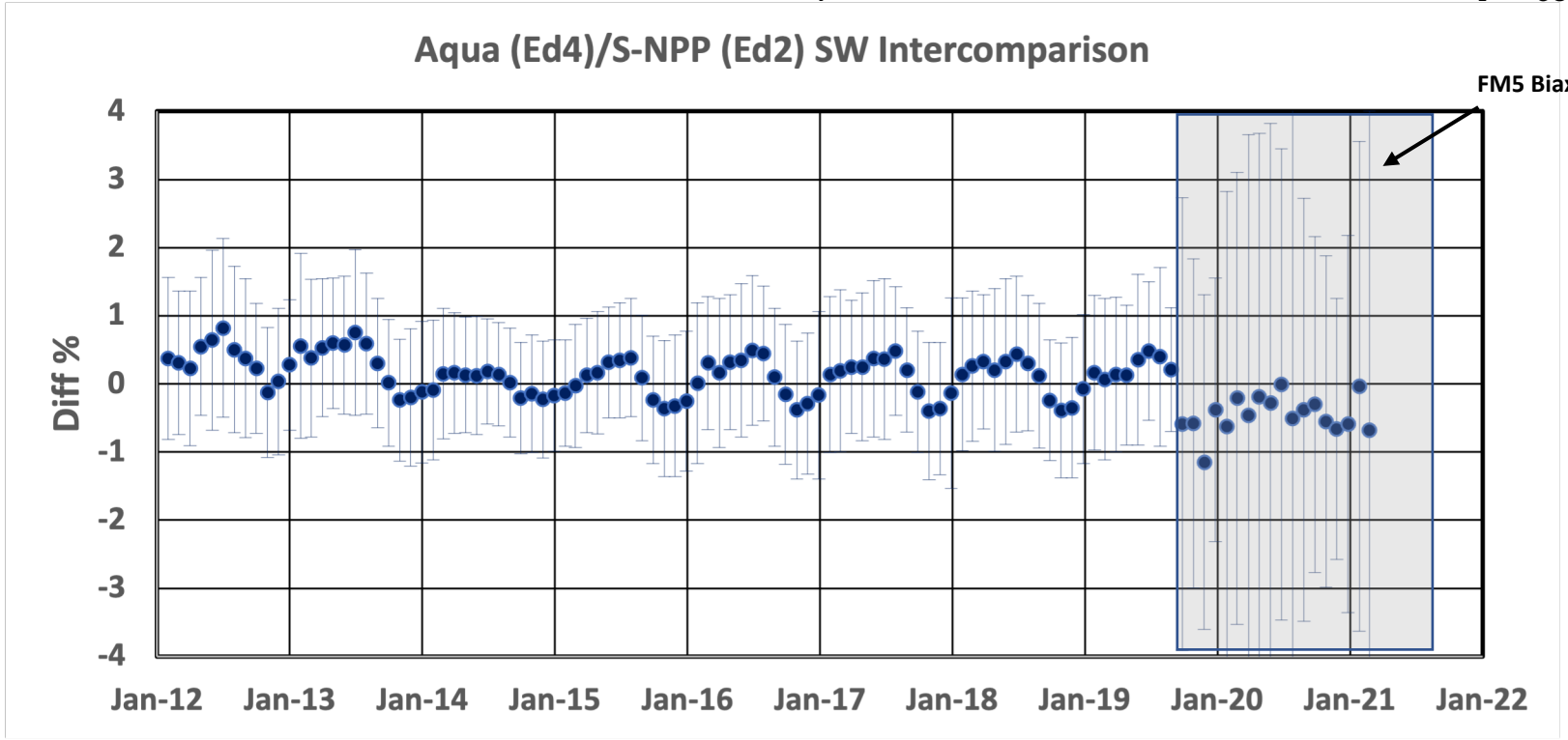
Aqua/S-NPP Intercomparisons

- The orbital geometries for Aqua and S-NPP are such that orbital overlaps occur every ~64 hours.
- Obtain spatially and temporally matched observations during every crossover.
- Use matching criteria to subset the data:
  - Lat. and Long. difference <= **0.05^0**
  - SZA, VZA difference < **2.0^0**
  - RAZ difference < **5^0**
- Obtain monthly all-sky SW reflectance, daytime and nighttime LW radiance differences using the matched footprints.
- *Since FM5 is now operating in biaxial mode, the number of matched footprints drastically reduces.*

FM3/FM5 SW All-sky Inter-comparisons: Feb 2012- Mar 2021

Difference of Reflectance:
FM3-FM5 %, 95% CI

$$Reflectance = \frac{SW_{rad} * \pi}{F * \cos(SZA)}$$ F=1361 W/m²



2014 data used for the radiometric scaling FM5 to FM3.

Data:
CER_SSF_Aqua-FM3-MODIS_Edition4A
CER_SSF_NOAA20-FM5-VIIRS_Edition1A

Larger differences observed after FM5 switched to biaxial mode are driven by the drastic reduction in number of spatially and temporally matched observations.

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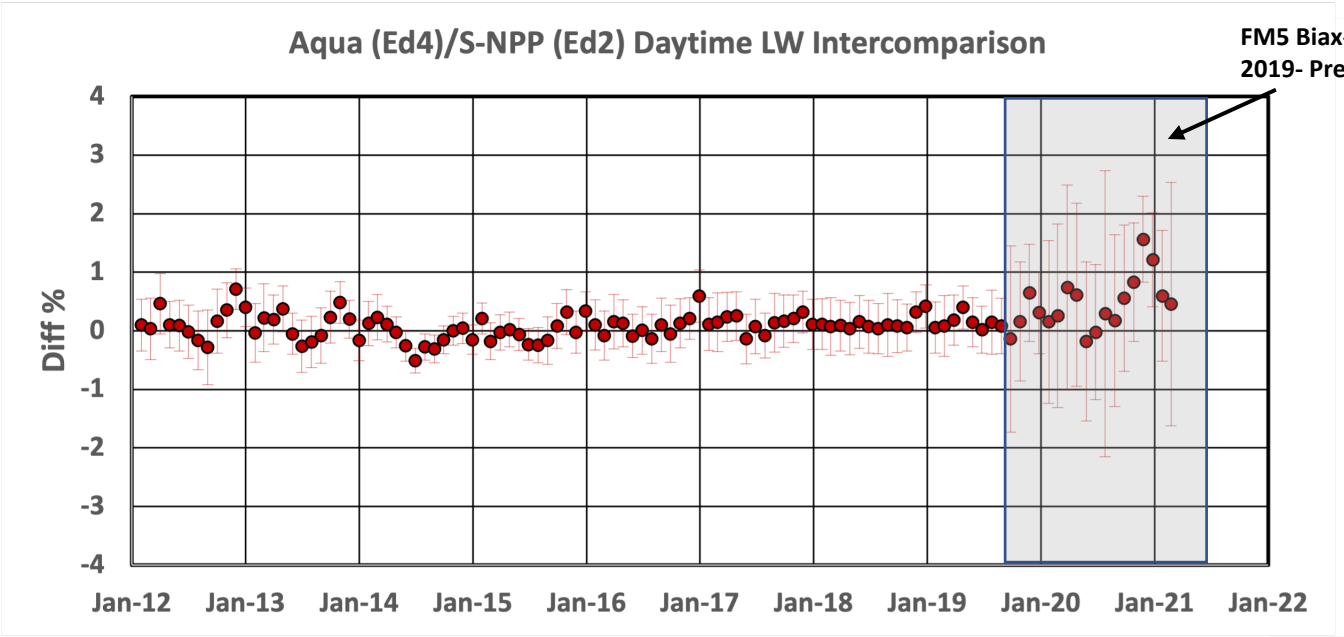
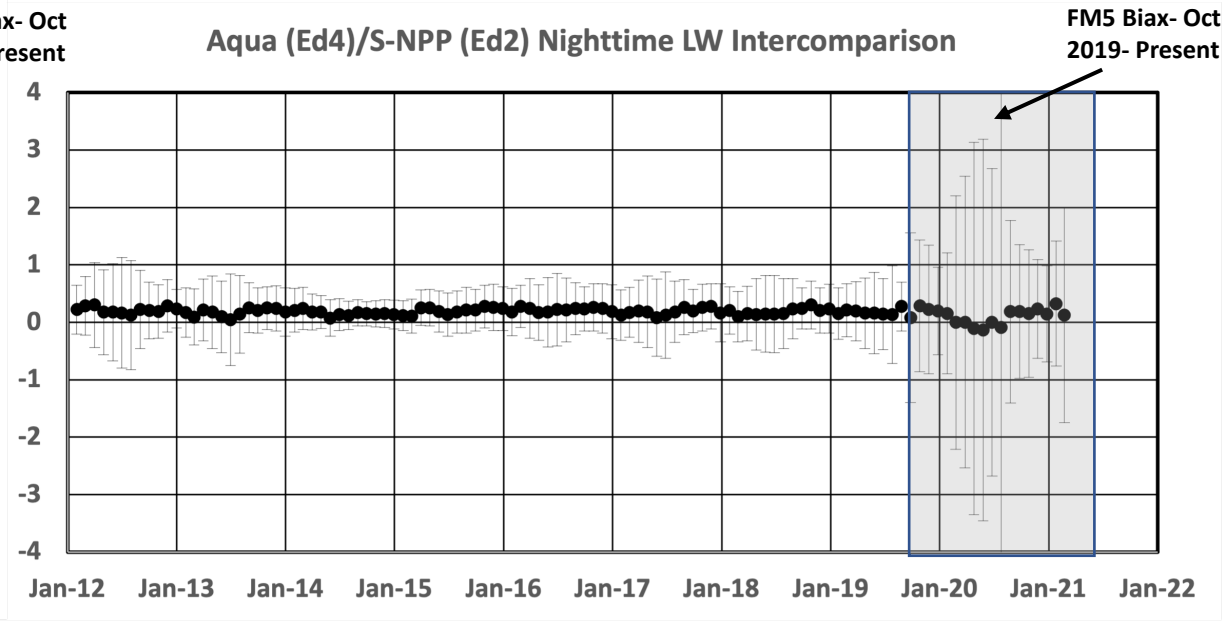
FM3/FM5 LW All-sky Inter-comparisons: Feb 2012- Mar 2021

Difference of Daytime Radiance:
FM3-FM5 %, 95% CI



Difference of Nighttime Radiance:
FM3-FM5 %, 95% CI



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Larger differences observed after FM5 switched to biaxial mode are driven by the drastic reduction in number of spatially and temporally matched observations.

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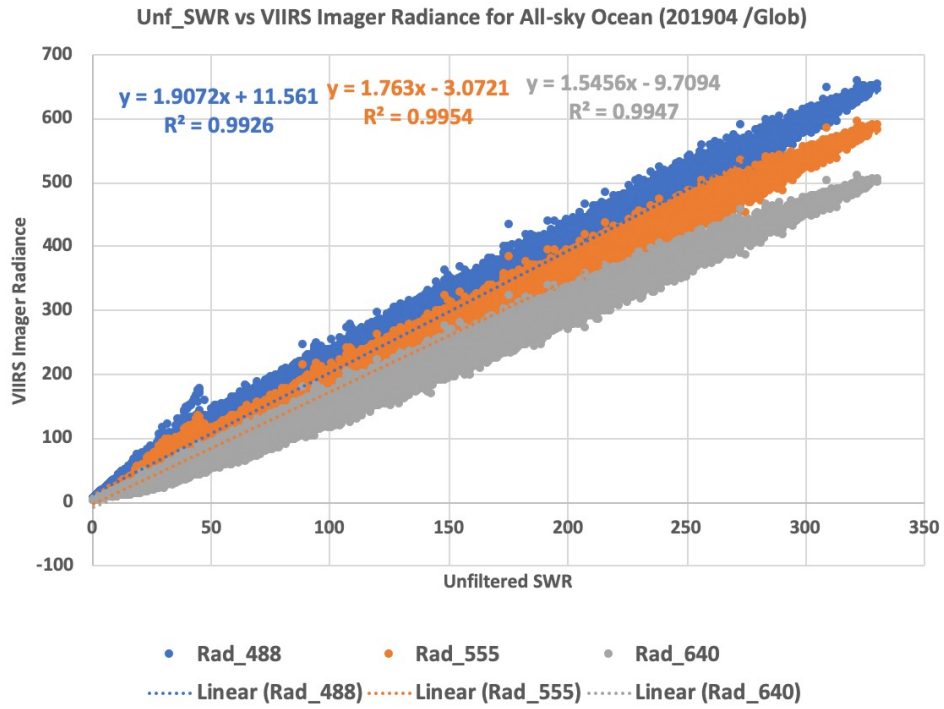
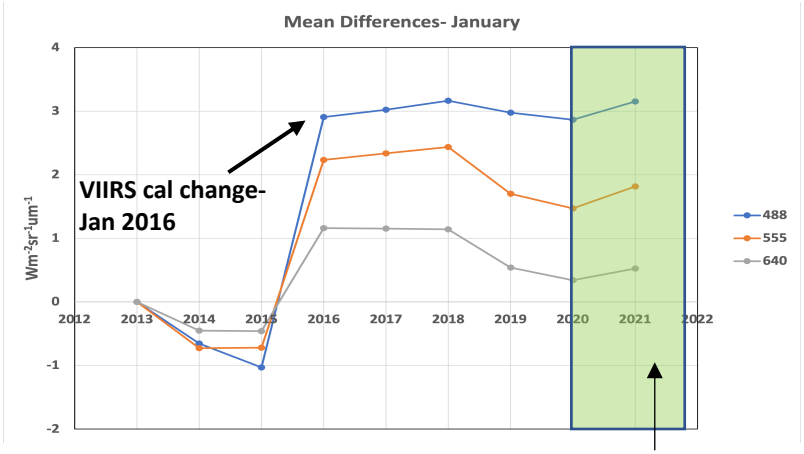
S-NPP CERES SW and VIIRS Comparisons

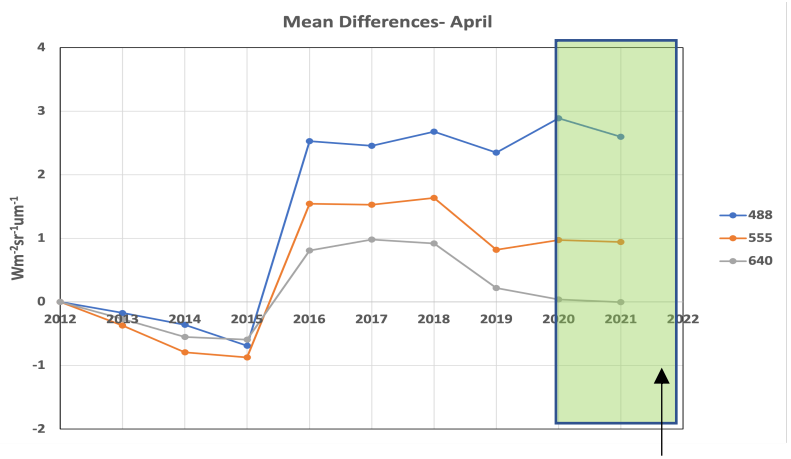
- Monitor any changes to relationship between CERES FM5 SW radiances and VIIRS radiances after FM5 transitioned to biaxial mode.
  - Use the 488nm, 555nm, and 640nm VIIRS channels.
  - Regressions performed monthly, using nadir all-sky ocean footprints.
  - Months from first year are considered ‘baseline’.
- After first year in mission, observe change in regression coefficients for every month across subsequent years:
  - Derive VIIRS radiance estimate using the regression coefficients of *corresponding month of baseline year*, for every CERES footprint (V1).
  - Derive VIIRS radiance estimate using the regression coefficients for the *current month*, for every CERES footprint (V2).
  - Calculate mean difference of (V1 – V2) across all CERES footprints.
- Any changes in CERES SW channel performance after transitioning to biaxial mode would change the slope of the regression, resulting in larger mean differences.
  - Assumes that VIIRS channels are stable.

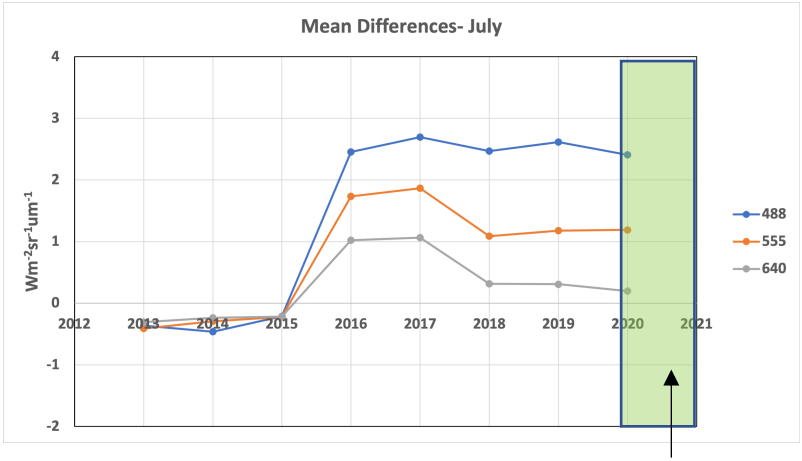


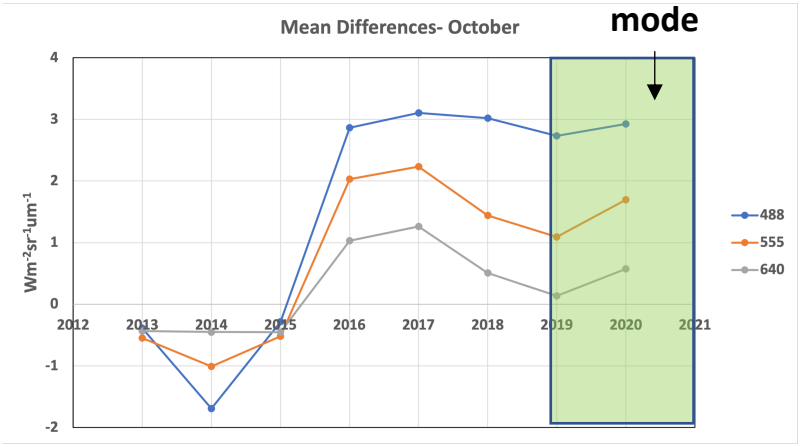
S-NPP CERES and VIIRS Comparisons

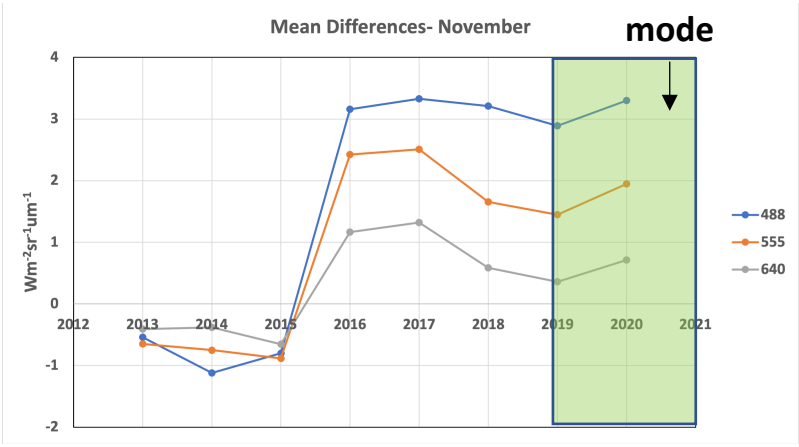
Difference in VIIRS Radiance Estimates

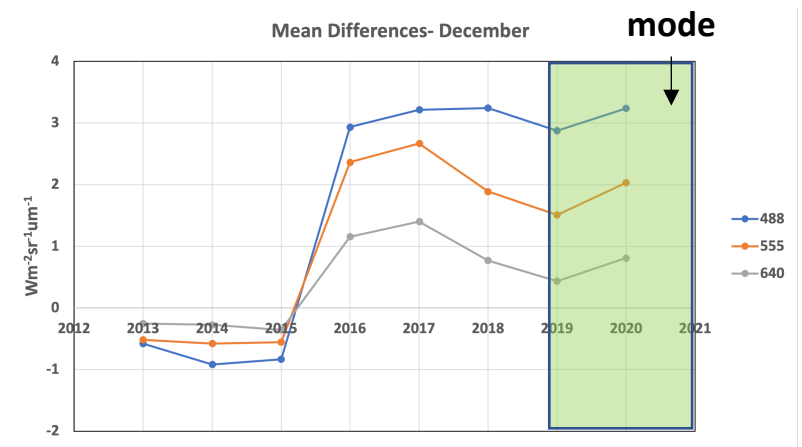












No observed change in the relationship between CERES FM5 SW channel and VIIRS on S-NPP after FM5 placed in biaxial mode of operation (October 2019).

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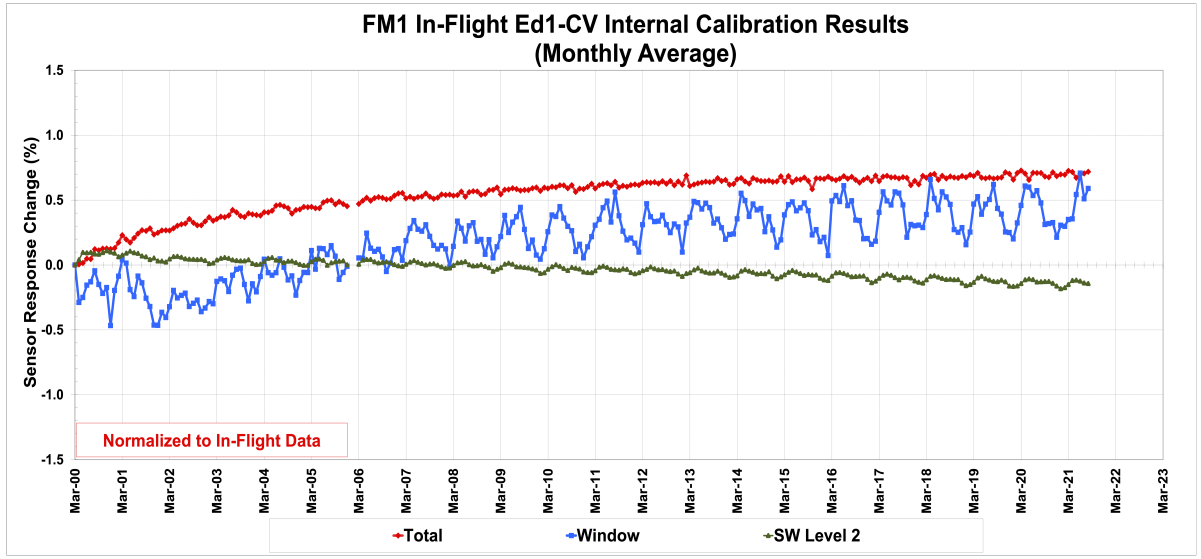
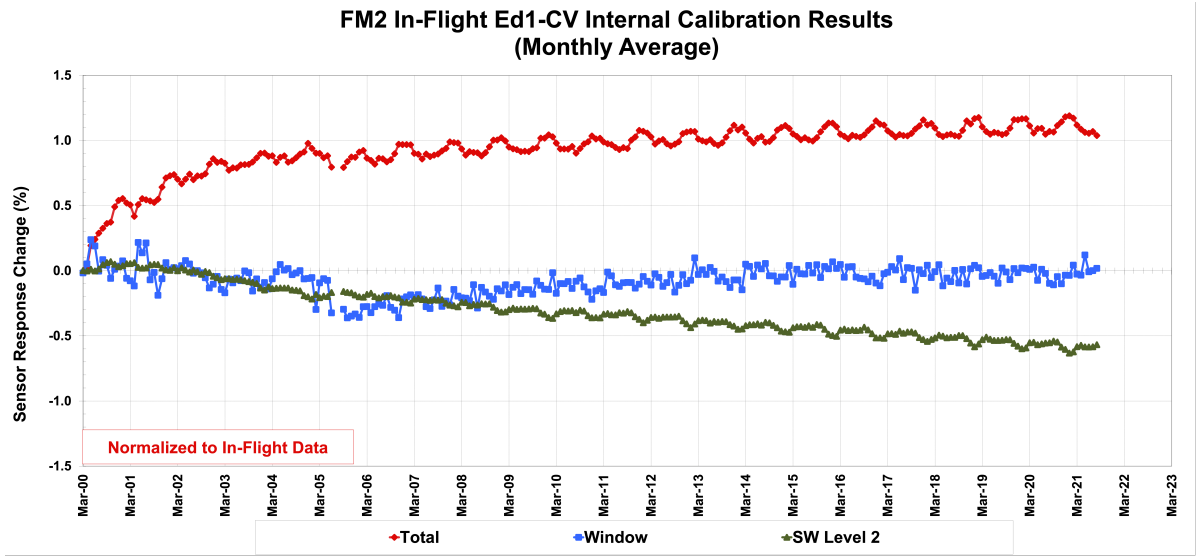
Terra & Aqua Instruments' Status
CERES FM1-FM4

Terra- FM1 & FM2 Internal Calibration

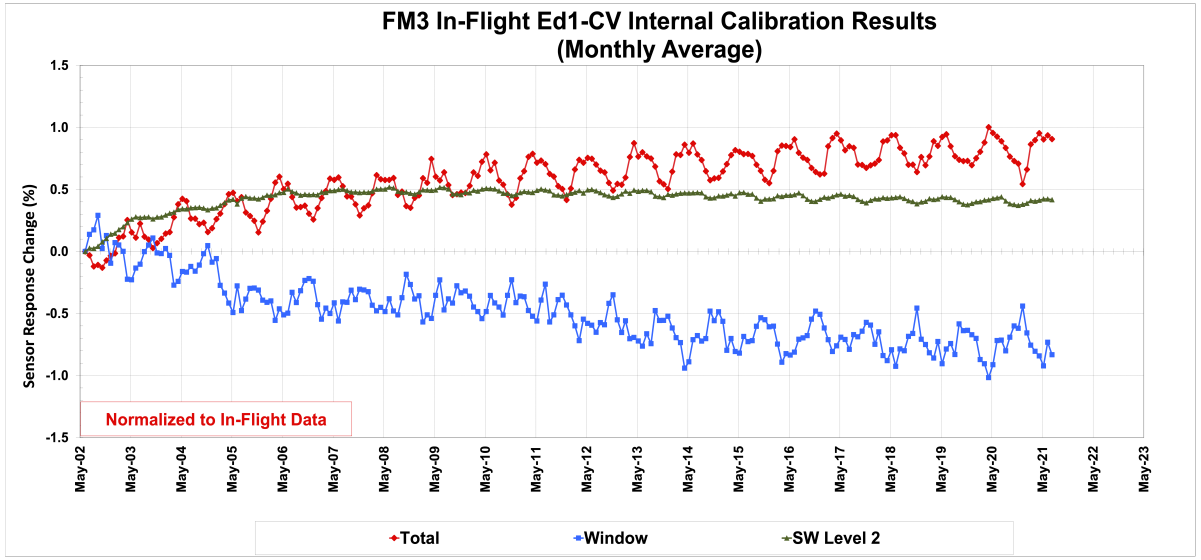
- **For FM1, TOT channel shows ~0.7% rise, SW channel shows ~0.1% drop, and WN channel shows a rise of ~0.5% since start of mission.**
- **For FM2, TOT channel shows ~1.2% rise, SW channel shows ~0.6% drop, while WN channel shows ~0% change since start of mission.**

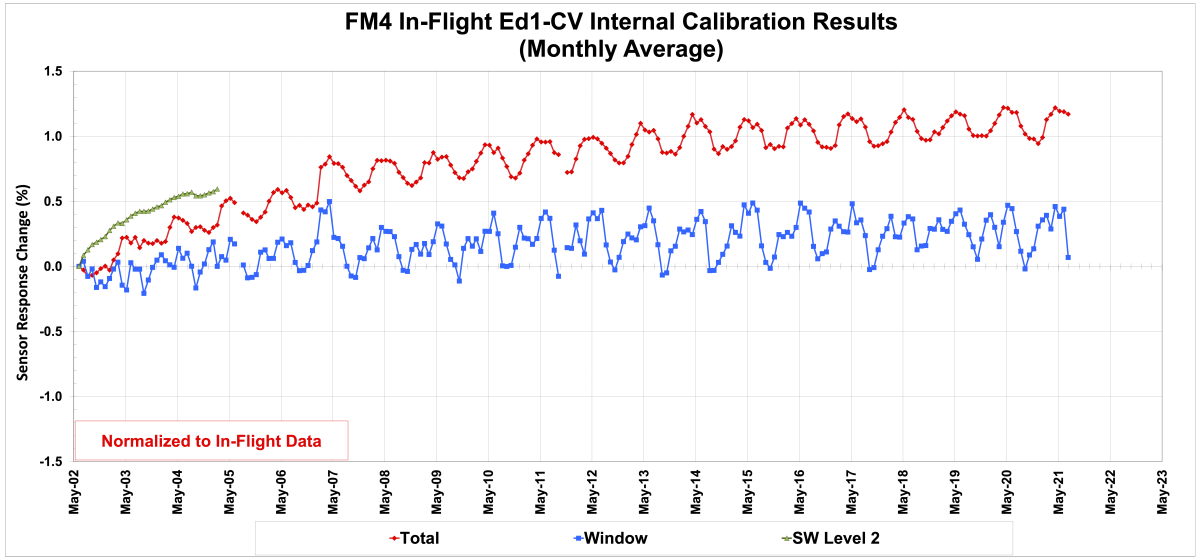




Aqua- FM3 and FM4 Internal Calibration

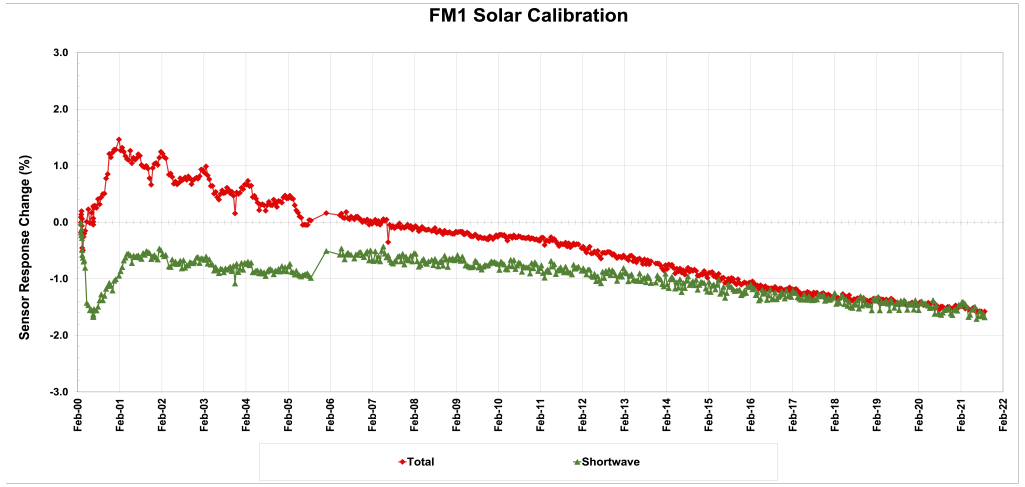
- **For FM3, TOT channel shows ~0.8% rise, SW channel shows ~0.4% rise, and WN channel shows ~0.8% drop since start of mission.**
- **For FM4, TOT channel shows ~1% rise, while WN channel shows ~0.25% rise since start of mission.**

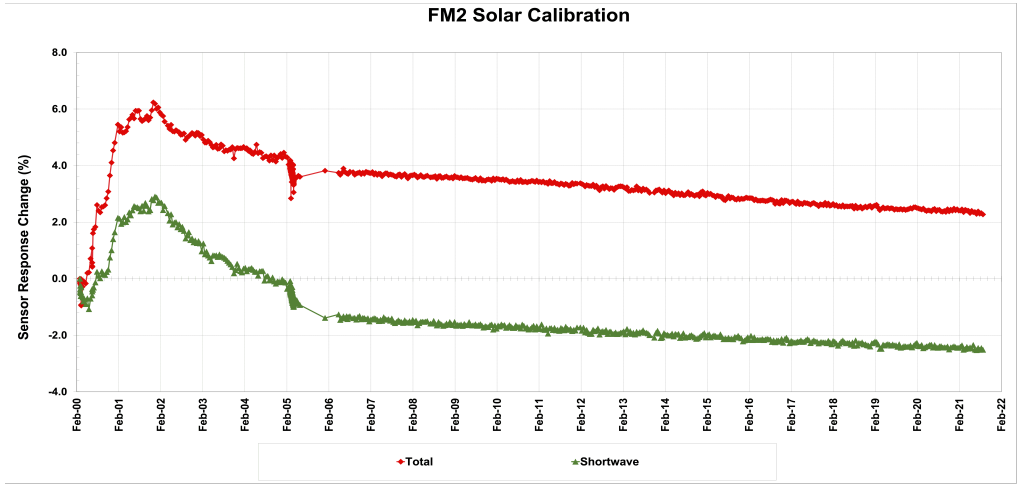


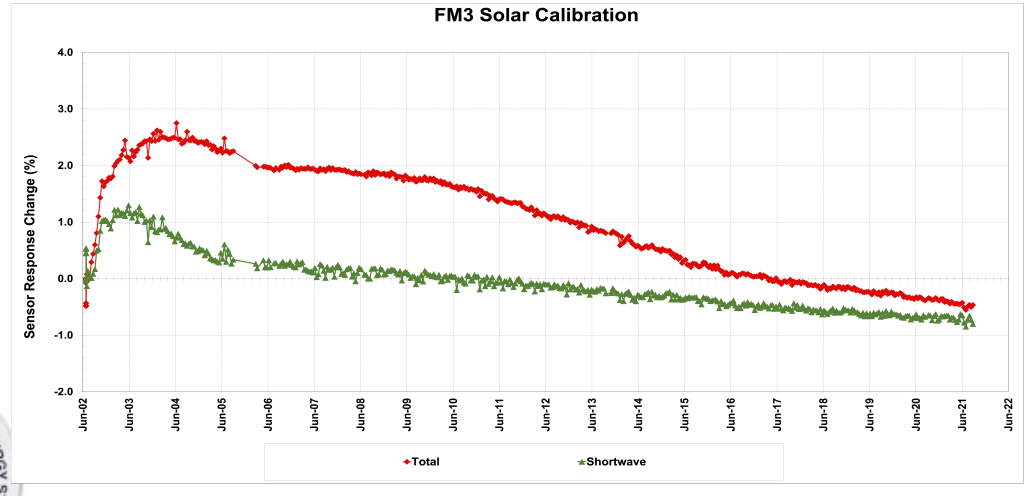


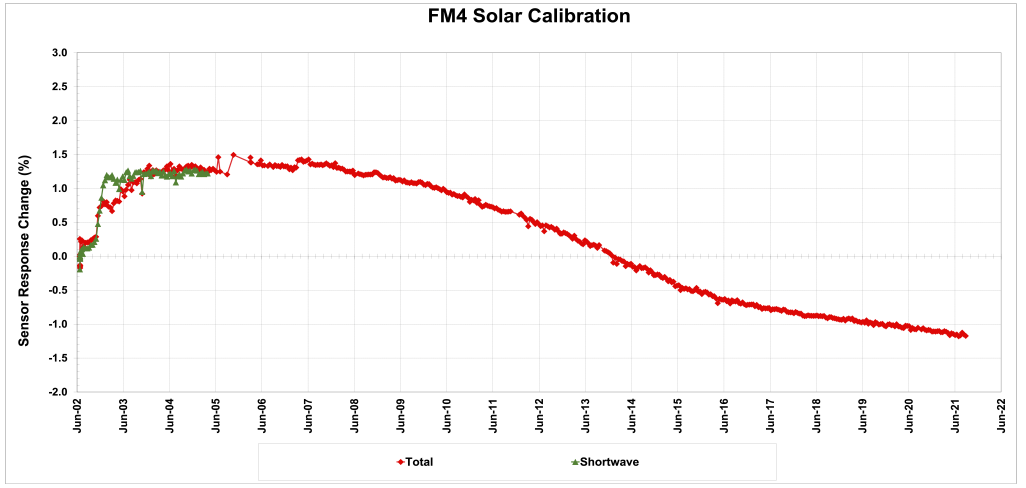
Terra & Aqua Solar Calibration

Since the start of raster scan for solar calibration, SW channel data shows a drop of response of ~1% and TOT channel shows a drop of 1.5%-2% for all instruments.

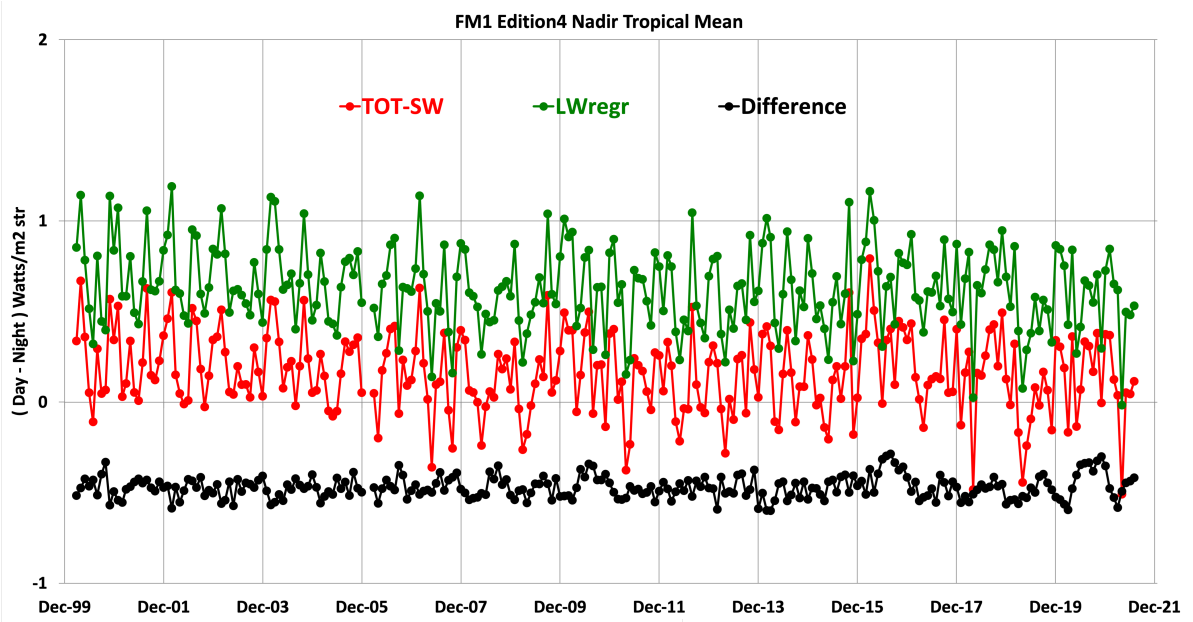


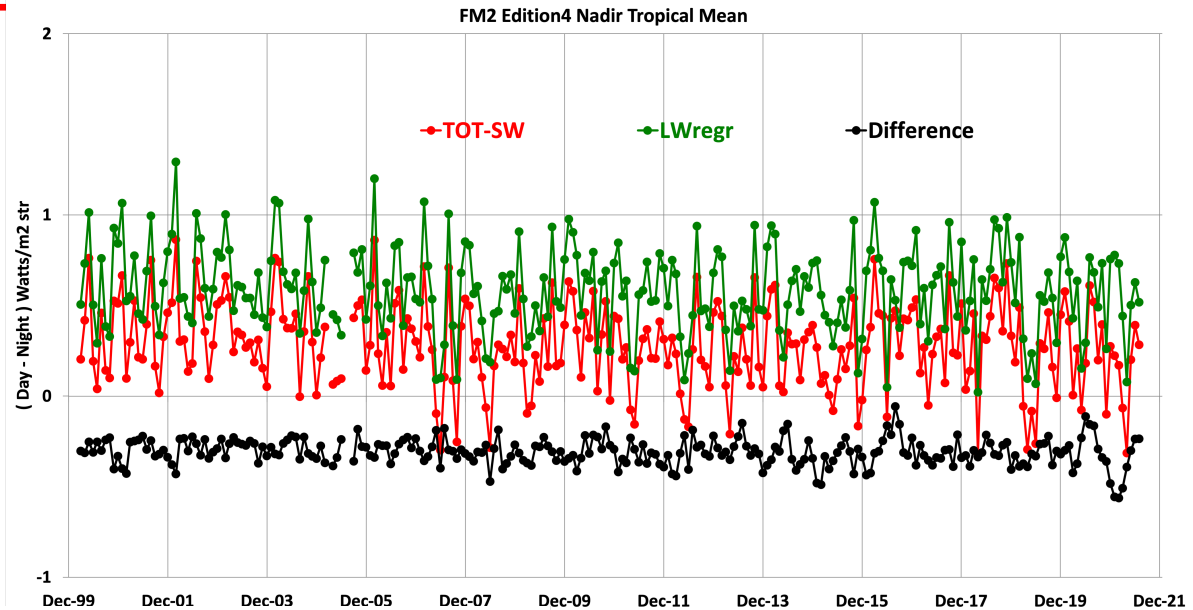


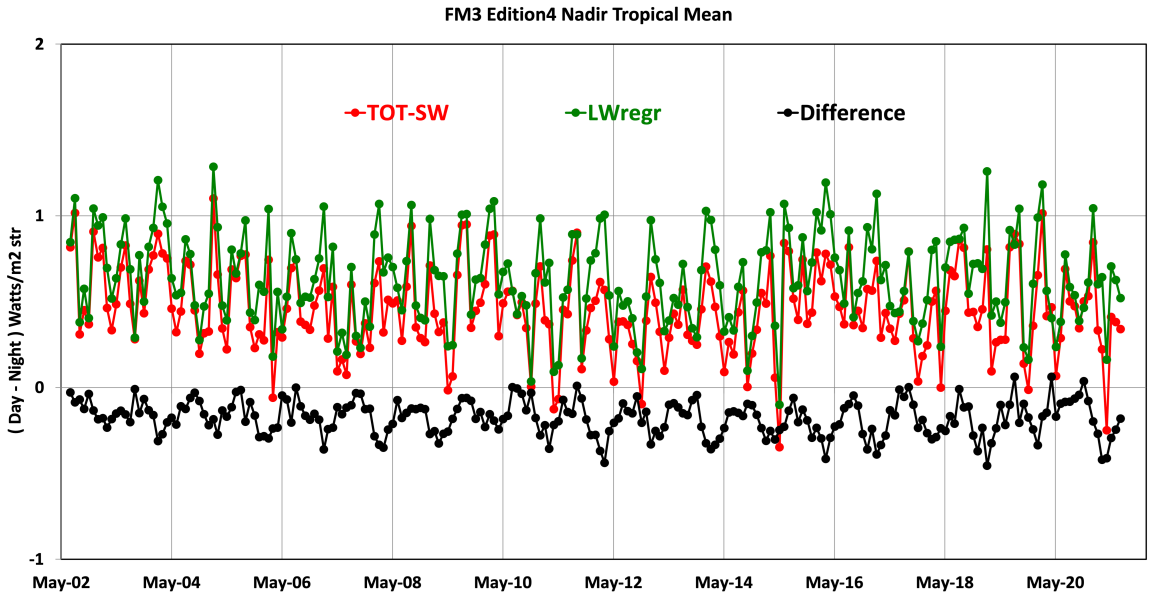




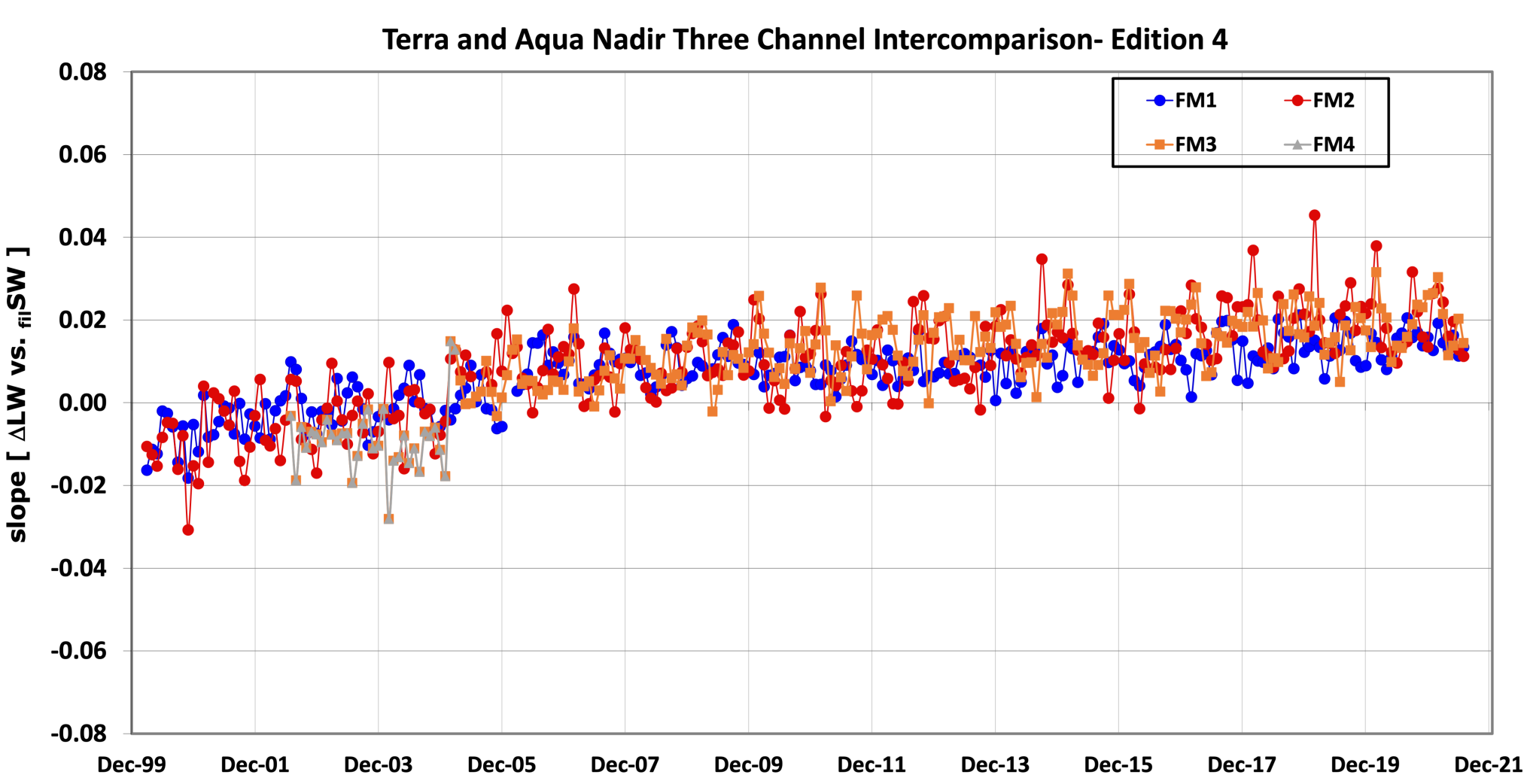
Validation- Terra and Aqua Tropical Mean



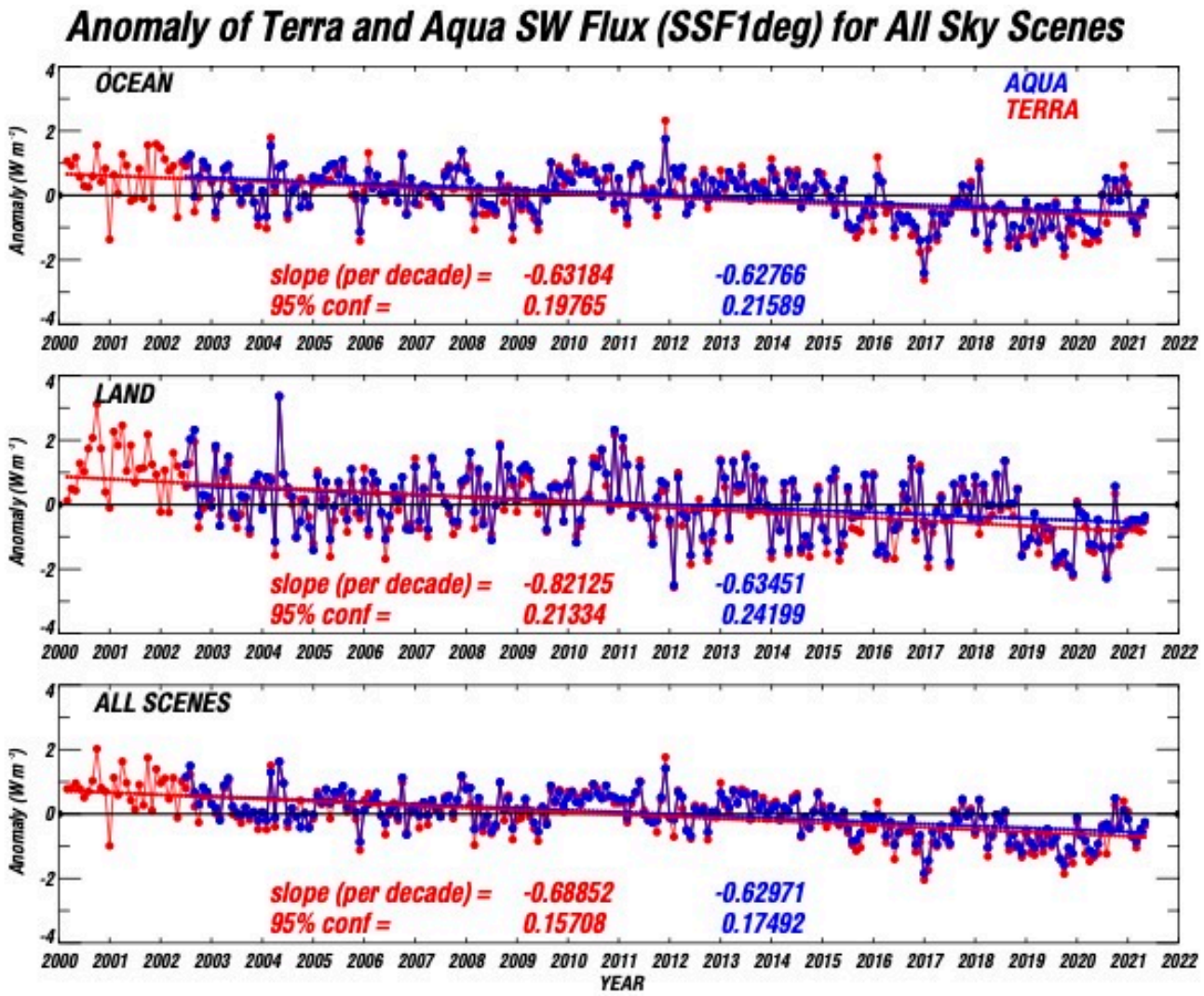




Validation- DCC 3-Channel Intercomparison



Validation: Terra and Aqua Ed-4 SW Flux Anomalies



SW flux anomalies show similar trends for Terra and Aqua

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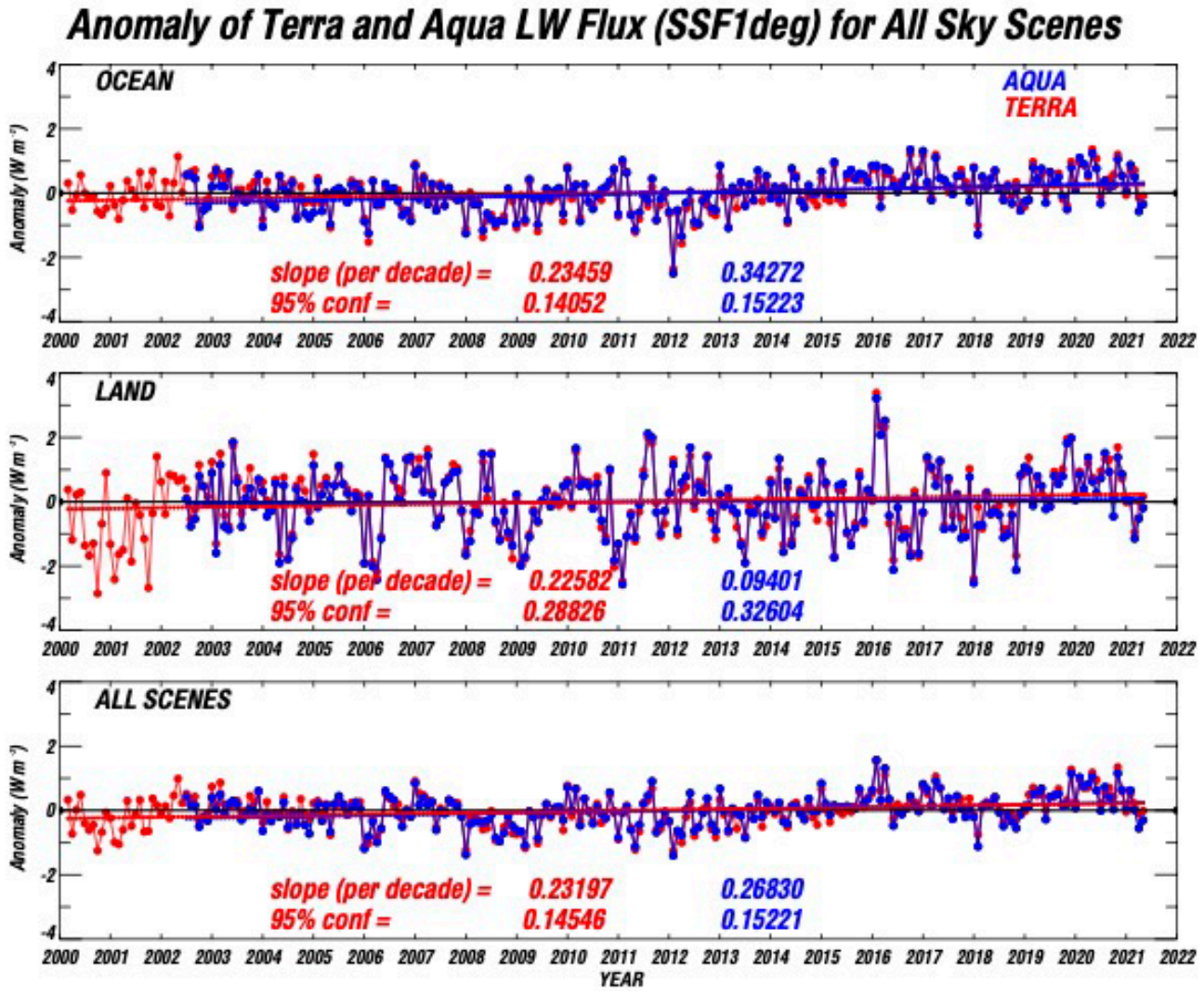
Validation: Terra and Aqua Ed-4 LW Flux Anomalies



LW flux anomalies show similar trends for Terra and Aqua.

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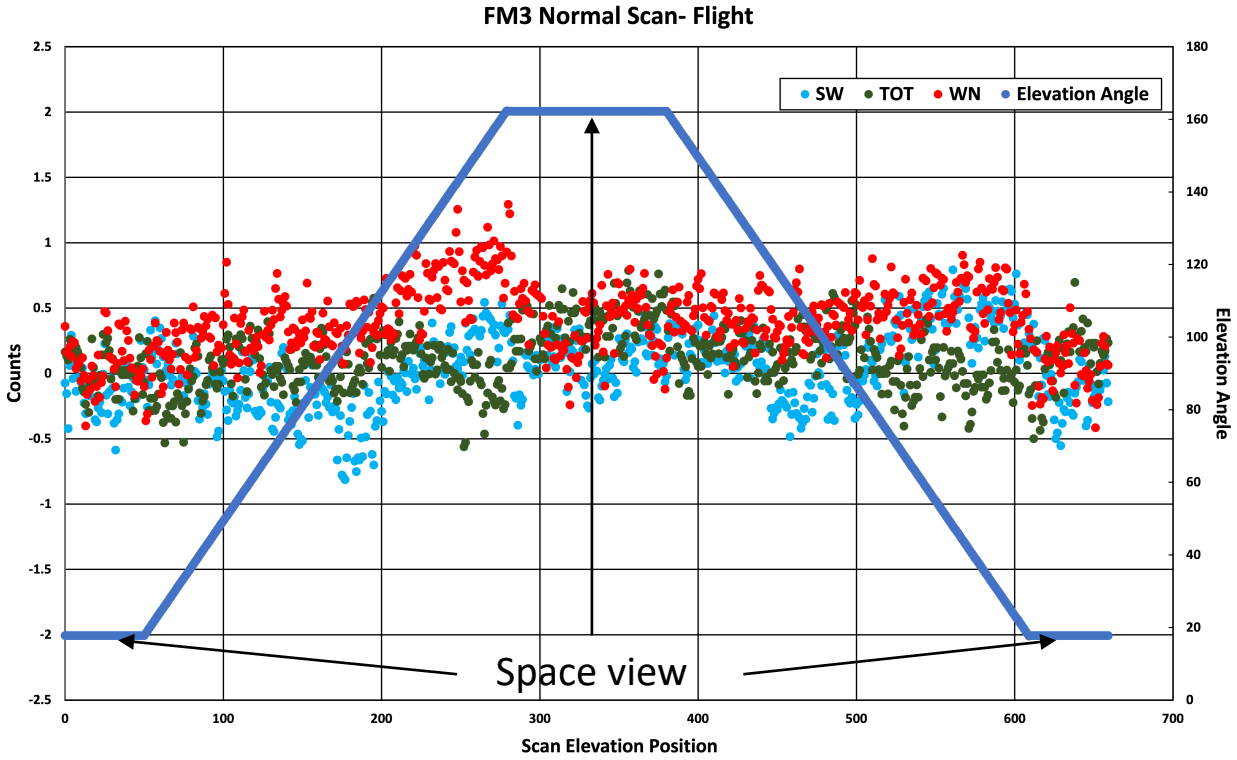
Aqua Deep Space Calibration

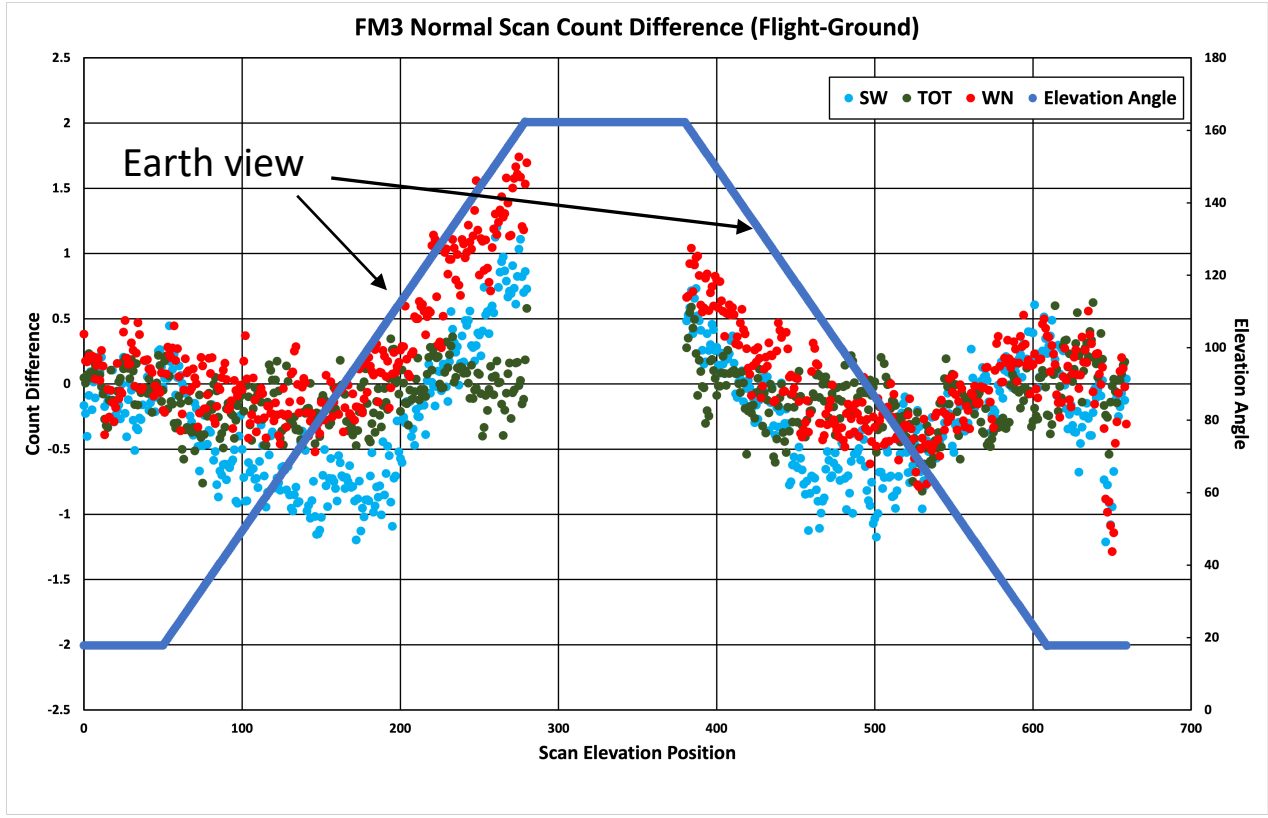
- An accelerated pitch-over maneuver during spacecraft night to provide science instruments calibration opportunities using the cold background of deep space and an option to view the moon.

- First ever DSC for Aqua, conducted on September 23, 2021, which included a view of the moon.
  - *Second DSC planned for November 4, 2021, without a lunar view.*

- For CERES, DSC provides the opportunity to measure the scan-dependent offsets and compare these to pre-launch measurements.
  - *Multiple scan modes tested- Normal scan, Short scan, nadir, double nadir.*

Aqua FM3 Scan Dependent offsets- Initial Look





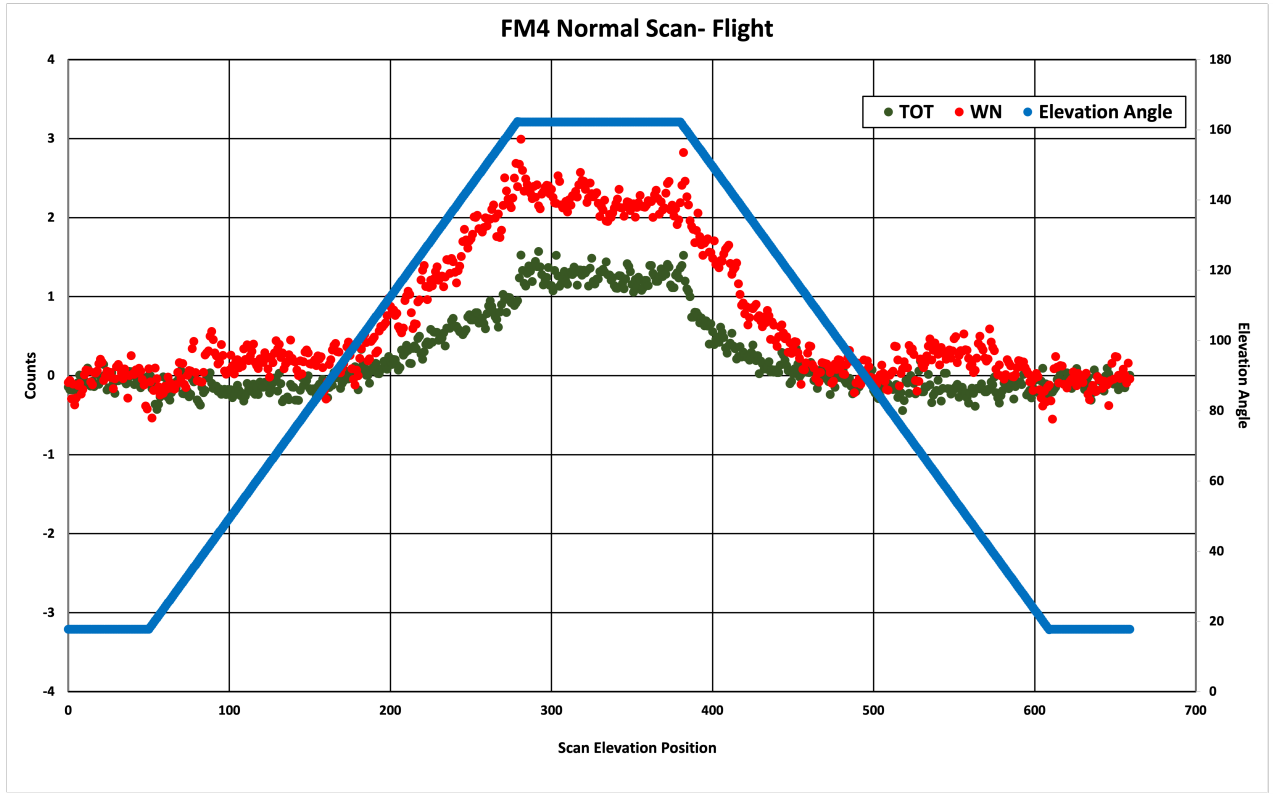
Differences:

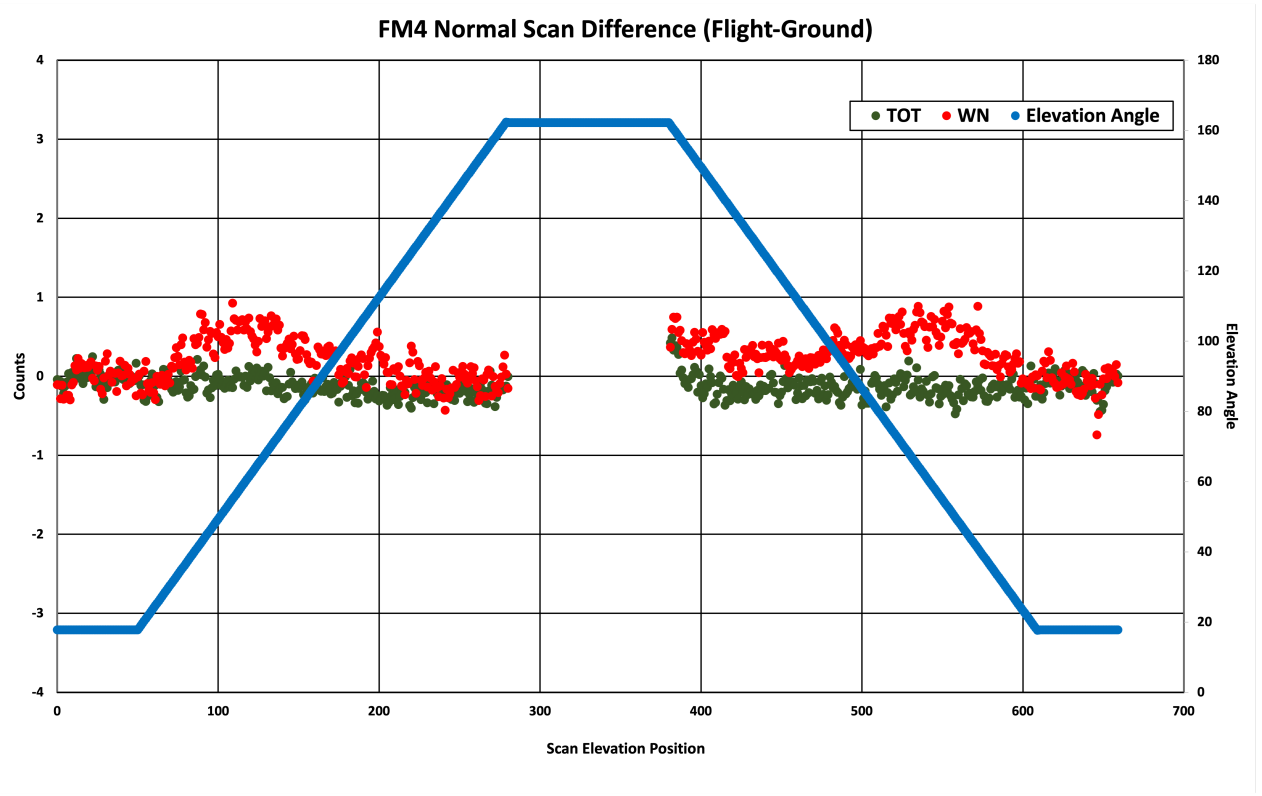
SW: ± 1 count

WN: ± 1.5 count

TOT: ± 0.5 count

Aqua FM4 Scan Dependent offsets- Initial Look





Differences:

WN: ± 0.5 count

TOT: ± 0.2 count

SUMMARY

- **All CERES instruments continue to perform nominally.**
  - **FM1-FM3, FM6 instruments currently operating in crosstrack mode.**
  - **FM5 is currently operating in full biaxial mode, collecting ADM data.**
    - ***Validation studies show no evidence of change to SW channel performance since transitioning to biaxial mode.***
  - **FM4 is currently operating in full biaxial mode.**
  - **Validations show that all instruments are performing consistently.**
- **Data products**
  - **NOAA-20/FM6 Edition 1 gains have been finalized and delivered through July 2021.**
  - **S-NPP/FM5 Edition 2 gains and SRFs have been delivered through July 2021.**
  - **Terra and Aqua instruments' Edition 4 gains and SRFs have been delivered through July 2021.**
- **IWG members participating in the Libera Calibration Working Group meetings.**

Backup

Instrument Product-line definitions

- **NOAA-20**
  - *Edition1-CV*: Products without any on-orbit instrument calibration corrections applied.
  - *Edition 1*: Incorporates the most up-to-date calibration corrections, radiometric scaling to Aqua.

- **S-NPP**:
  - *Edition 1-CV*: Products without any on-orbit instrument calibration corrections applied.
  - *Edition 2*: Incorporates the most up-to-date calibration corrections, radiometric scaling to Aqua, and time varying SRF adjustments to TOT channel.

- **Terra/Aqua**:
  - *Edition 1-CV*: Products without any on-orbit instrument calibration corrections applied.
  - *Edition 4*: Incorporates the most up-to-date calibration corrections, radiometric scaling and time varying SRF adjustments to SW and TOT channels.